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SOVIET SOIL SCIENCE

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SOVIET SOIL SCIENCE

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ROLE OF SOIL SCIENCE IN THE DEVELOPMENT OF AGRICULTURE IN THE USSR¹

I. V. TYURIN, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

The development of soil science in Russia proceeded from its very inception with the participation of soil scientists in the solution of major problems of the national economy. The principal problems were the comparative evaluation of properties of land for various purposes, including first, the reclamation of new land for agriculture and second, the increase of soil productivity. Examples of this are the classical work of V. V. Dokuchayev and his co-workers on the study of the Russian chernozem and of the soils of the Nizhegorodskaya and Poltavskaya states in the late 19th century. These studies, undertaken for the purpose of raising the level of agriculture in the chernozem belt, and for comparative evaluation of the land, made possible the establishment of the scientific basis of contemporary soil science and development of the complex historical method of the study of soils which is now universally accepted.

In the post Dokuchayev period, at the beginning of the 20th century, large soil cartographic investigations were made under the direction of Professor Glinka in the Far East, in Siberia and in Central Asia, to reclaim agricultural land of the new sparsely populated regions of the country. At the same time, in European Russia, investigations were carried out in many of the states to properly organize a network of agricultural experiment stations. As a result of the foregoing work, a large amount of material was accumulated. The analyses and generalizations of these data led to important scientific conclusions in the fields of genesis, and classification and geography of soils which became internationally known.

After the great October Socialist Revolution, the need for utilizing the accomplishments of soil science to further the national economy of the country increased greatly. Soil science in the USSR was given much wider possibilities for the development of investigational work in all its subdivisions. This, in turn, made it possible to widen the scope of the work and the participation of soil scientists in solving problems that faced the agriculture of the country in connection with the transition into the socialist type of development.

Development of Soil-Cartographic Work and Its Utilization in Long-Range Planning of the Agriculture of the Country

The work of studying and mapping soils was given considerable attention during the entire history of soil science in Russia and in the USSR. That this development was greatly accelerated after 1917 can be seen from the data shown in Table 1.

Presently, over half of the Soviet Union, including all the agricultural regions of the country, have soil maps of small and medium scales. At the same time, with the marked increase of volume of soil cartographic work in the last 40 years, an improvement in methods of field and laboratory investigations of soil is taking place. The content and the form of maps is being improved. The classification and systematization of soils and the legends of soil maps are more precise.

The most significant work in this direction was done in the last 15 years in connection with the preparation of the General Soil Map of the USSR, on which all the local sub-divisions of the soils were compiled into a unified system and soil nomenclature for the entire Soviet Union. The basic principles of this system were developed by the V. V. Dokuchayev Soil Institute, Academy of Sciences, of the USSR, and consist of the following.

The soil group, in the sense that it closely corresponds to the concept of the European soil scientists and in a somewhat more restricted sense to the concept of the "great soil group" of the American authors, has been accepted as the basic taxonomic unit. Each soil group includes several soils which developed under similar or the same bioclimatic and hydrologic conditions and are characterized by one type of soil profile. The number of basic soil groups as set up by V. V. Dokuchayev and N. M. Sibirtsev at the beginning of the 20th century did not exceed twelve. At the present time, as a result of establishing new ones and partly of sub-dividing the old, (i.e., the known soil groups) their number greatly increased and, for the territory of the USSR amounts to 60.

Soil groups, in turn, are sub-divided into genetic sub-groups, which include normal, (i.e., the most characteristic for the given group) and

¹ Paper presented by I. V. Tyurin before the 6th International Congress of Soil Scientists held in the United States in 1960.

Table 1

Development of soil cartography in Russia and in the USSR
from 1897 to 1957

Scales	From 1887 to 1917	From 1918 to 1957
Detailed soil surveys 1:50,000	Individual farms	About 250 million hectares
Medium scale surveys 1:50,000 - 1:200,000	About 150 million hectares	About 500 million hectares
Small scale surveys 1:300,000 - 1:1,000,000	About 450 million hectares	About 1200 million hectares
Reconnaissance soil maps 1:2.5 mill. - 1:4 million	European Russia without the Caucasus	Entire territory of the USSR

transitional, which have some characteristics of other groups. For instance: sub-groups of the podzolic group include podzolized surface, gley-podzolic, and bog-podzolic soils; chernozem group includes sub-groups of thick and ordinary chernozem, leached chernozem, calcareous chernozem, solonetzic chernozem, etc.

Recently a designation of local provincial sub-groups (or several sub-groups) has been adapted on the basis of their hydrothermic regime, which has essential productivity importance.

Shown on large-scale maps within each sub-group are genetic species (variations) and varieties determined on the basis of characteristics of a given soil group such as: the degree of podzolization for the podzolic soil groups, the organic content for the chernozems, etc.

Along with the sub-divisions based on bioclimatic, hydrologic, and hydro-geologic conditions of soil formation, there is a sub-division on the basis of particle-size analysis and of lithological properties of the parent material, for instance, clay and fine clay loam, clay loam (medium, and coarse) sandy loam, sands, stones, etc.

Thus classification and systematization of USSR soils are based on consistent use of the genetic principle for the establishment of taxonomic units, ranging from the soil group to the soil species or variety. In the concrete designation of groups and species and variety of soils, the genetic group and sub-group are retained, making it easy for wide circles of practical workers in agriculture and forestry to understand the soil maps and giving the soil scientist the possibility of wider comparisons and generalizations.

It should be mentioned that the consistent use of the genetic principle makes it possible to improve further the systematization of soils on the basis of a more complete consideration of all the soil properties and the conditions of their development. Systematic work in this direction is being carried on at present.

The use of a single system of soil classification and systematization in soil mapping facilitates the use of soil maps of small and

medium scales in solving planning problems of large undertakings. Specifically, soil maps serve as a basis for regional soil-agronomic planning in the USSR. The problems of agricultural specialization and differential application of various systems of agriculture are solved on the basis of such planning.

Of great value in planning future development of agriculture in the USSR is the inventory of land, that is, the determination of areas occupied by different soils for the entire country, and for individual administrative and economic regions. This work, which was started about 30 years ago by Academician L. I. Prasolov, is now being carried out in the V. V. Dokuchayev Soil Institute (under the direction of N. N. Rosov) on the basis of the newest soil-cartographic data. As a result of this work, the area occupied by the several groups and sub-groups is determined as is the degree of utilization of these soils. Data of such an inventory are necessary to determine the extent of land suitable for agricultural reclamation and the order in which work in reclaiming new land in various zones and regions should be carried out and, also, the volume of work and of investment necessary.

An outstanding example of utilizing soil maps in the solution of such problems was the preliminary determination of the areas of virgin and abandoned land suitable for agriculture (without melioration), for the planting of grain crops in eastern regions of the country. This preliminary work, conducted by the Dokuchayev Soil Institute, was the basis for the government decision of 1954 on the reclamation of virgin and abandoned lands of Siberia, Kazakhstan, and Trans-Volga. In 1954, a considerable number of soil scientists carried out work on locating, selecting, and designating suitable land for the organization of new sovkhozes. Thus, the total area of land in agricultural use in 5 years reached 36 million hectares.

In the near future soil scientists of the USSR will have to carry out a large program of study and comparative evaluation and selection of new land suitable for reclamation on the vast territory of the sub-taiga belt in the European part of the USSR, in Siberia, and in the Far East.

Work on Detailed (Large-Scale) Soil Mapping in Kolkhozes and Sovkhozes

Another important branch of soil investigation,

which is directly connected with problems of raising soil productivity is the work on the detailed or large-scale study and mapping of soils of the kolkhozes and sovkhozes.

Before the great October Socialist Revolution, such work was not developed because of the extensive character of agriculture in the country. It was then limited to the preparation of large scale soil maps of individual progressive estates and of some experiment stations and experimental forests.

The beginning of extensive work on large scale soil mapping dates to the end of the 1920's. New problems in agriculture which faced the Soviet state, namely the organization of large grain producing sovkhozes and the creation of collective farms, the beginning of the application of lime and of commercial fertilizers, the development of irrigation construction, etc., demanded the preparation of large-scale maps on scales of 1:10,000 - 1:50,000 on areas of tens of millions of hectares. This work was widely developed in 30 years, but had to be discontinued during the great war of the fatherland. During the war years, the greatest part of the soil maps of kolkhozes and sovkhozes in the zone of occupation were destroyed.

The resumption of work on the preparation of large-scale soil maps in the post-war period began at the end of the forties and was intensively developed during the last 10 years (1950-1960). Large-scale mapping has been completed on the territory of about 250 million hectares.

It must be pointed out, however, that the quality of maps made at different times was not uniform, and that not in all cases was the utilization of the soil maps by the kolkhozes and sovkhozes satisfactory. It was especially true with respect to maps prepared before the war, and partly in the first post-war years, because of weak methodology and often unsatisfactory organization of the work.

In 1953, this situation led the Dokuchayev Soil Institute and the journal "Pochvovedeniye" to propose radical improvement of the organization and methodology for carrying out detailed soil-mapping of the kolkhozes and sovkhozes to insure a more effective utilization of results of such mapping in increasing agricultural productivity. At present Soviet republics have created proper organizations to conduct the work in accordance with much improved programs which include the following: 1) preparation of soil maps, 2) agricultural and meliorative characteristics of the soil, and 3) development of recommendations on the organization of the land area of farms and carrying out practices and meliorative undertakings for increasing the productivity of each farm unit. The most intensive work of this type developed in recent years in the territory of the Ukrainian SSR, where large-scale soil mapping and investigations (on a scale of 1:10,000 - 1:25,000) of all agricultural land on an area of about 47 million hectares were undertaken. This work is being done with a unified methodology developed by the scientific investigational agencies of the Ukrainian Academy of Agricultural Sciences.

The elementary (i.e., the lowest) taxonomic

unit in this work is the soil species, which is understood to be a unit of soil with uniform profile (i.e., it corresponds to the soil species of the general classification system of USSR soils) and uniform with respect to stable agricultural characteristics. In other words, the soil species in the Ukrainian work is taken as a uniform agricultural genetic unit.

Soil species are grouped into larger agricultural groups characterized by approximately uniform basic agricultural characteristics, including particle-size analysis and type of parent material, the position on the relief, the moisture conditions, and the degree of cultivation.

The end product of these investigations for each kolkhoz or sovkhoz consists of a soil map (on a scale of 1:10,000 - 1:25,000) and a cartogram giving individual agricultural properties of the soils, or recommendations for conducting various types of soil improvement practices. In addition, for each farm unit (i.e., kolkhoz or sovkhoz) a monograph is prepared which contains a description of the soils shown on the map, the characteristics of the soil species and agricultural groups of soils, the climatic, topographic and other natural conditions, with recommendations on tillage, fertilization, melioration and soil erosion control, etc. Groups of scientists who prepare the practical recommendations include agronomists.

The experience of the Ukrainian SSR is now being utilized in working out analogous programs in other republics. It should be noted that aerial photographs are used extensively in the preparation of detailed soil maps at present. This makes it possible to delineate soil boundaries more precisely and to differentiate them on the basis of the Dokuchayev principle of the relation between the genesis of the soil and the factors (and conditions) of soil formation.

Soil Investigations for Special Purposes

To evaluate the contribution of soil science in the development of agriculture, mention should be made of special soil melioration investigations.

These studies are of great importance in irrigation which in the USSR is used primarily in dry and hot regions of Central Asia and Transcaucasus. In the past irrigation has been often followed by secondary salinization. Without special detailed study of irrigated soils and of their water-salt regime, it is impossible to anticipate, prevent, or eliminate this secondary salinization. This realization led to the development of melioration soil studies (field surveys and laboratory investigations) in the USSR.

Intensive development of soil reclamation investigation took place after 1921, in connection with large melioration works and the reconstruction of old and construction of new irrigation systems designed to increase the cotton production of the country. During the last 40 years, investigations were carried out and maps were prepared on all the territory which is now under irrigation. Areas suitable for irrigation were investigated also. The general objective of these studies, in addition to a real investigation and detailed mapping, was to determine the laws

governing salt movement and accumulation in soil under irrigated agriculture and to forecast secondary salinization, as well as finding rational methods to prevent and combat salinization.

For the successful solution of these problems a special methodology was developed. This methodology provides for the study of soils, sub-soils and of ground water in relation to the salt content in the entire water-holding layer of the soil and also the study of physical constants and functional water physical properties of soils on which the water-salt regime of the soil and of the entire irrigated area depend. The application of this methodology requires the concurrent work of soil-mapping and of field observations on key areas, and the continuous operation of experiment stations. This is being followed in irrigated regions.

One can appraise the contribution of soil science to the development of irrigated agriculture in the USSR by the following. After the 1917-1921 period the area of irrigated land in the USSR more than doubled and now it exceeds 10 million hectares. All irrigation projects were carried out with the utilization of the results of preliminary detailed soil melioration investigations. As a rule, this ensured successful operation of the created irrigation system and effective systems of melioration and practices. As a result of this, the greatest part of the land previously abandoned for reasons of secondary salinization was ameliorated and put back into cultivation. Still larger areas of desert, virgin land were converted into highly productive land and are guaranteed against secondary salinization. In connection with these results, the area of cotton in the USSR has increased 2 and a half times in the past 30 years and average yields were raised by more than 20 centners of raw cotton per hectare.

Of course, these results in irrigated agriculture were attained as a result of a combination of: favorable social-economic conditions; high level of mechanization and agricultural practices; and the use of fertilizer. However, the above-mentioned factors can be effective only when they are applied on the basis of results of thorough soil and melioration investigations.

In the irrigated regions detailed soil investigations of the land of the kolkhozes and sovkhoses are being repeated in order to control the improved conditions of the soil and to develop a more suitable, improved system of agriculture and ameliorative practices to correspond to soil properties—to raise all crop yields, particularly cotton.

Other types of special soil investigations which were of considerable help in successful solution of various agricultural problems of the USSR include the soil investigations in the non-chernozem belt, for the designation of land requiring lime, and selection and study of soils in various parts of the Caucasus for the establishment of tea and citrus plantations, as well as the creation of shelterbelts in steppe regions and the investigation of soils in regions inundated in connection with the construction of large hydro-electric stations, etc. In all work of this type a common system of soil classification was used which was supplemented by grouping of the

soils according to those characteristics which are important for the particular undertaking.

The Role of Soil Science in Development of New Methods of Raising Soil Productivity

One of the new approaches in soil science is the attempt of soil scientists to work out new methods to increase soil productivity, utilizing chemical, physical, melioration and biological methods for this purpose, and at the same time, keeping in mind the genetic peculiarities of various soils.

The effectiveness of organic and mineral fertilizers on the principal soil groups was studied in the combined investigations of soil scientists and agricultural chemists. It was found that the effectiveness of mineral fertilizer is much greater on soils of the more humid northern regions, i.e., on the podzolic and gray forest soils, and on the degraded and leached chernozems. On soils of the drier zones of the ordinary and southern chernozems, and of the dark chestnut soils, the effectiveness of fertilizer is greatly reduced. It appears principally in relatively wet years. The central sub-zone of deep chernozems occupy an intermediate position with respect to the effectiveness of mineral fertilizer.

With high applications of fertilizer (1.2 cntn per ha) the greatest effect is found on all soils from nitrogen, next phosphorus, and finally, potassium. With medium rates of applications (0.45 - 0.60 cntn per ha) this order is changed on the deep and ordinary chernozems where phosphorus takes the first place, nitrogen the second, and potassium the last, except in the deep chernozems and the old sugar beet regions where it is as effective as nitrogen.

The study of fertilizer effectiveness under irrigated conditions showed that in the regions of recent agriculture in the southern chernozems, in the chernozems of Caucasian foothills, and in the chestnut soils of the Trans-Volga, irrigation is a greater factor in increasing yields than is the application of fertilizer, although fertilizer effectiveness, especially in the case of corn and alfalfa, is quite high. This shows that the amounts of plant nutrients which are available with irrigation in the soils of these regions are still high, and that correct agricultural practices can insure high yields. In the older agricultural regions with sugar beets, the amount of available plant nutrients which can be utilized with irrigation is much smaller and, therefore, irrigation (of wheat) gives a lower effect than the application of fertilizer. The highest effectiveness of mineral fertilizer, particularly nitrogen fertilizer, on irrigated land has been found for cotton on the sierozems of Central Asia.

Thus the effectiveness of fertilizer on various soil groups varies and depends on the moisture supply and on the amount of plant nutrients capable of being transformed into available forms. The degree of effectiveness is determined by the type of soil, by the various degrees of exhaustion and the relation between elements as a result of continued long-time agricultural utilization without fertilization.

The conclusions cited are used as a basis for the differential application of fertilizer in various soil zones and economic regions of the country and are used in working out long-term plans for the development of the fertilizer industry and for the distribution of fertilizers in the different regions of the country.

Another example of successful utilization of the achievements of soil science in agriculture is the development of effective methods of amelioration and of agricultural reclamation of solonetz soils which are widespread in the dry zone of chestnut soils and in the chernozem zone.

Work on the genesis of solonetz and the principles of their chemical amelioration by means of replacing exchangeable sodium with calcium was done by the outstanding Soviet scientist, Academician K. K. Gedroyts. Later, these basic principles were developed further by other authors who introduced new suggestions in order to simplify and to make the methods available for basic improvement of solonetz soil. These methods include those in which the exchangeable sodium is replaced by calcium by utilizing the gypsum or calcium carbonate contained in the lower horizons of the solonetz itself. For this purpose the soil is plowed deeply and the moisture content is increased either by snow retention or by irrigation. To accelerate the reaction of replacement of exchangeable sodium by calcium from its carbonate (when gypsum does not exist), an important additional practice in the case of irrigation is the planting of perennial crops (alfalfa), growth of which increases the CO_2 content of the soil and increases the solubility of calcium carbonate. These methods were tried and gave positive results both under experimental and field conditions. This points to the possibility of wide reclamation of large areas of virgin land in the dry steppes of the southeastern and eastern regions of the country where the presence of a large number of spots of solonetz precluded the possibility of reclaiming this land.

It is not possible in such a short paper to report on other examples of successful participation of soil scientists in finding and developing new ways of increasing soil productivity in the various natural zones of the country. We should mention such methods as meliorative plowing of sod-podzolic soils to a depth of 40 cm, which improves the water regime of soil and causes the stable increase in yields for a number of years, especially during dry years. The successful application of magnesium fertilizer on sandy soils and other methods should be noted also. Many studies in this direction are now in the process of development and testing, and one can expect that they would produce effective results.

Problems of Controlling Erosion in the USSR

For a number of reasons the processes of

soil erosion on the territory of the USSR, except for some mountainous regions and highly dissected elevated plateaus, do not have the intensive development as in the United States of America, as reported by Bennett. Only in the last 20 or 30 years have erosion processes become the subject of intense attention and study on the part of Soviet soil scientists. Their existence and the danger of erosion processes in the chernozem belt was, however, pointed out by Dokuchayev almost 70 years ago. Recent work made it possible to delineate areas affected by intensive water and wind erosion and to determine categories of eroded soil and obtain an approximate idea of the dimensions of annual soil losses caused by erosion, which appeared to be appreciable. The problem of controlling erosion phenomena and the elimination of their negative consequences are now commanding the attention of many soil scientists and other specialists.

At present, systems of general and zonal practices of soil conservation are being developed by soil scientists and other specialists in the study of soil erosion. These practices are included as requirements which are presented to the kolkhozes and sovkhozes when detailed soil investigations are carried out. In this way general application of these practices is being accomplished.

Conclusions

We have attempted to give a general idea of the role of soil science in the agricultural development and in the general progress of agriculture in the USSR. We soil scientists are not prone to exaggerate these roles. On the contrary, we often express regrets that the achievements of soil science are insufficient and are not utilized rapidly in the practice of agriculture. Great destruction caused by the war necessitated the restoration of normal living conditions and normal agriculture over a long period of time. Naturally, under such conditions there was no possibility of utilizing all the achievements of science, including the achievements of soil science for the agricultural development.

This restoration stage has been concluded and the socialist agriculture of the Soviet Union now has leaders determined to advance agriculture through complete utilization of the achievements of science. If the hopes of all peoples for the establishment of a general and firm peace, and the elimination of the danger of a new war could be realized, one can be sure that the future progress of agriculture in the USSR will go on with increasing success and that an important role will be played in this success by the achievements of soil science.

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AMOUNT OF AVAILABLE AND SOLUBLE PHOSPHATES IN SOILS OF THE SUGAR BEET ZONE AND METHODS OF DETERMINING THE AMOUNT OF SOIL PHOSPHORUS

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The purpose of our investigation was to determine the increase in the amount of available phosphates in soils of the sugar beet zone following the systematic application of fertilizer, and concurrently, the suitability of various chemical methods of evaluating the amount of available phosphates in the soil.

With the cooperation of workers of Ukrainian experimental stations and of the Central Chernozem Zone of the Russian Soviet Federal Socialist Republic, soil samples were collected from fields with different levels of phosphate application. In the sugar beet zone there remain almost no field experiments in which there are treatments without the application of phosphates. As a rule, the controls received phosphorus in band application for sugar beets, winter wheat, and corn. In the majority of experiments the effects of phosphate application were studied on fields in which 20 tons of manure and band application of phosphates were made. Under such conditions it is difficult to find experiments which would show clearly the positive action of phosphates. However, it was possible to find a sufficient number of soil samples to determine a strong increase in the amount of available phosphates in cases where fertilizer was applied.

Soil samples for the gray forest were taken from the Poltava Agriculture Experiment Station from an experiment in which fertilizer application and crop rotation (started in 1937) were conducted, and from a field in continuous rye where for 74 years no fertilizer was applied. Phosphate fertilizer at this experiment station did not have a strong effect.

Samples of podzolized meadow-chnozem soil of coarse texture were taken from the experimental field of the Ukrainian Institute of Agriculture, near the city of Kiev, from an experiment entitled, "Single-Enrichment of Soil with Phosphates," which was started in 1949.

At the Ramon and L'gov experimental stations soil samples were taken of leached chernozem from an experiment on the study of systems of fertilizers and crop rotation which started in 1936.

Soil samples of northern low humic, thick chernozems were taken from the Belotzerkov, Drobov, and Mironov experiment stations from

experiments designed to study systems of fertilizer and crop rotations. At the Mironov station soil samples also were taken from an experiment designed to study continuous cropping with mineral fertilizer. The experiments at the Drobov and Belotzerkov stations were started in 1948, at the Mironov station, in 1912 and in 1929.

A sample of soil also was taken at the Kirov kolkhoz, which is located near the Drobov Experiment Station.

Soil samples of thick chernozem were taken at the Ivanov, Sumsk, and Khar'kov experiment stations from experiments on the study of fertilizer and crop rotation systems, which started in 1937, 1952, and 1956. In addition, at the Sumsk Experiment Station soil samples were taken from an experiment on the effectiveness of local and basic application of mineral fertilizers for sugar beets. Positive effects of mineral fertilizer were shown at all of these stations.

Soil samples of solodized-carbonate chernozem taken at the Veselopodoliansk Experiment Station from an experiment on the study of fertilizer systems started in 1948 in the Sotzshliakh kolkhoz.

In accordance with the nomenclature accepted in the published pages of the State Soil Map, we accepted three groups for the leached and thick chernozems: thick, leached, and northern low humic, thick chernozems in the Ukraine.

The chemical characteristics of soils are given briefly in Table 1, where mean values of the analyses for each soil group are shown. Total phosphorus was determined by combustion according to Lebediantsev, humus according to Tyurin, adsorbed bases were determined by replacement with 1 N solution of ammonium acetate, and the hydrolytic acidity was determined by the method of Kappen.

The average values obtained showed that the thick chernozems were richest in humus and in adsorbed bases and had a considerable hydrolytic acidity. The leached chernozems also were rich in humus, but they were lower in adsorbed bases and their hydrolytic acidity was high. The northern chernozems differ from the leached by a lower content of humus and of exchangeable bases. The gray forest soils and podzolized meadow-chnozems were characterized by low

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Table 1

Chemical characteristics of soils

Soils	Total P ₂ O ₅ mg 100g of soil	Humus %	Hydrolytic acidity, meq/ 100 g of soil	pH (KCl)	Adsorbed bases, meq /100 g	
					Ca	Mg
Gray forest	70	1,9	3,5	5,6	17,8	8,6
Podzolized meadow-chno- zem	52	2,9	2,1		14,0	2,2
Leached chernozem	92	4,8	3,8	6,3	27,6	6,8
Northern low humic, thick chernozem	91	3,5	3,1	6,0	23,2	3,11
Thick chernozem	91	4,8	2,5	6,5	33,9	8,9
Thick solodized carbonate chernozem	99	4,6	—	—	34,2	5,0

Note: Comma represents decimal point.

contents of humus, of exchangeable bases, and of total phosphorus. The amount of available and soluble phosphates in the soil was determined by the method of Sokolov (1, 2).

The amount of available phosphate in the soil and its degree of availability were determined by pot experiments, using the radioactive isotope of phosphorus P³² in the form of a radioactive tracer with a negligible content of the carrier P³¹.

The amount of available phosphate was computed by the formula below:

$$P_{\text{supply}} = \frac{P_{\text{plant}} \times 100}{K}, \text{ where}$$

P_{plant} is the amount of the tracer phosphorus in 100 grams of soil which enters the plant; K is the percent utilization of P³², which, other things being equal, characterizes the degree of available soil phosphates.

Pot experiments were replicated three times. The Radioactive tracer was added in amounts of 100 microcuries for each pot. The experimental plants were spring wheat, "Moskovka." The mean error of the experiment m_D = ±0.59 g/vessel.

The content of phosphorus and of radioactivity of the mature plants was determined by measuring the radioactivity in 0.2 gram samples in measuring tube AC-2.

To ascertain the suitability of existing chemical methods for determining readily soluble phosphates in all the soil samples, we determined the soluble phosphates for extracts of Truog (0.002 normal H₂SO₄), Chikikov (0.5 normal CH₃COOH), Egner-rim (solution of calcium lactate), and Kirsanov (0.2 normal HCl).

The radioactive tracer P³² with a negligible amount of the carrier was added to the solutions used in the preparation of the extracts. Knowing the original radioactivity of the solution and having determined the radioactivity of the extracts and their phosphorus content (by the

method of Denizh-Shmook with determinations on the photoelectric colorimeter), it was possible to determine not only the content of phosphates in the extract, but also the secondary precipitation during the preparation of the extracts and the total content in the soil of soluble phosphates, i.e., the sum of phosphates remaining in the liquid phase (in the extracts) and that which reverted back to the solid phase—the soil.

The average results of the experiment and analyses according to groups are given in Table 2. In the experiments on the thick and leached chernozems the application of fertilizer resulted in doubling to tripling the supply of available phosphate in the soil, in spite of the fact that the plots which were designated "without fertilizer" actually received fertilizer in the band. On the gray clay loams of the Poltava station, the plots "without fertilizer" contained a good deal of available phosphate. In the podzolized meadow-chernozem and the solodized carbonate chernozem there was no great increase in phosphates, but for such soils we had samples of only single experiment stations.

Along with the increase in the supply of available phosphates, there took place an increase in the degree of availability of the phosphates which is characterized by the value of "K", that is, by the percent of utilization of the radioactive tracer.

This was the result of systematic application of fertilizer. Thus, systematic application of phosphates in usual agrotechnic rates on chernozem soils in the zone of sugar beets not only increases the amount of available phosphates two to three times, but also brings about a qualitative improvement of these amounts, that is, it leads to enriching the soil with more readily soluble, available phosphates.

The results of the determination of the soluble phosphates in the soil were confirmed by the pot experiments. The application of fertilizer led to a marked increase in the amount of soluble phosphates in the soil.

The evaluation of the results of the analyses is made by means of borderline indices (limits).

Table 2
Amount of soluble and available phosphates in soils of the sugar beet regions

Index	No. of deter- minations	Amount of soluble phosphates				Amount of available phosphates	Utiliza- tion of psr, % "K"
		0,002 n H ₂ SO ₄	0,5 n CH ₃ COOH	Calcium lactate	0,2 n HCl		
Gray forest soils							
Average amount, mg P ₂ O ₅ in 100 g of soil	15	30,1	30,0	8,3	26,1	13,4	20
Same for non-fertilized treatments	5	27,8	26,4	5,1	20,8	12,4	18
Same for fertilized treatments	10	31,4	31,8	9,9	28,8	13,8	20
Content of P ₂ O ₅ in extract, in % of amount	15	63	38	73	50	—	—
Amount of fertilized treatments, in % of supply of non-fert.	—	113	120	194	138	111	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,81±0,14	0,57±0,23	0,54±0,23	0,67±0,20	—	—
Podzolized meadow-chernozems							
Average amount, mg P ₂ O ₅ in 100 g of soil	8	12,9	12,6	2,2	15,7	2,4	10
Same for non-fertilized treatments	2	9,4	8,0	1,2	10,4	2,2	8
Same for fertilized treatments	6	14,1	14,2	2,4	17,5	2,6	12
Content of P ₂ O ₅ in extract, in % of amount	8	72	36	63	41	—	—
Amount of fertilized treatments, in % of supply of non-fertil.	—	150	178	200	168	118	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,48±0,36	0,46±0,36	0,49±0,28	0,71±0,29	—	—
Leached chernozems							
Average amount, mg P ₂ O ₅ in 100 g of soil	9	29,4	30,2	10,2	30,7	18,6	24
Same for non-fertilized treatments	2	18,1	18,9	3,0	26,2	10,5	20
Same for fertilized treatments	7	32,6	33,4	12,3	32,0	20,9	25
Content of P ₂ O ₅ in extract, in % of amount	9	65	42	70	52	—	—
Amount of fertilized treatments, in % of supply of non-fertil.	—	180	177	410	122	199	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,99±0,05	0,99±0,05	0,99±0,05	0,86±0,19	—	—

Note: Comma represents decimal point.

Table 2 (continuation)

Index	No. of deter- minations	Amount of soluble phosphates				Amount of available phosphates	Utiliza- tion of p ₂₅ , % "K"
		0,002 n H ₂ SO ₄	0,5 n CH ₃ COOH	Calcium lactate	0,2 n HCl		
Northern low humid, thick chernozems							
Average amount, mg P ₂ O ₅ in 100 g of soil	26	32,6	31,8	9,2	37,4	12,9	29
Same for non-fertilized treatments	8	23,3	25,0	3,4	29,5	7,4	21
Same for fertilized treatments	18	36,8	34,3	11,7	41,1	15,3	32
Content of P ₂ O ₅ in extract, in % of amount	26	74	58	70	59	—	—
Amount of fertilized treatments, in % of supply of non-fertil.	—	158	137	375	139	207	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,96±0,06	0,81±0,12	0,90±0,09	0,94±0,07	—	—
Thick chernozems							
Average amount, mg P ₂ O ₅ in 100 g of soil	15	21,1	21,6	5,2	29,0	9,4	22
Same for non-fertilized treatments	4	15,7	16,5	3,0	24,6	5,5	20
Same for fertilized treatments	11	23,1	23,4	6,0	31,5	10,8	24
Content of P ₂ O ₅ in extract, in % of amount	15	65	40	65	48	—	—
Amount of fertilized treatments, in % of supply of non-fertil.	—	147	142	200	128	19,5	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,98±0,06	0,95±0,07	0,95±0,09	0,95±0,09	—	—
Thick solodized-carbonate chernozems							
Average amount, mg P ₂ O ₅ in 100 g of soil	6	26,8	19,7	5,7	27,9	5,6	26
Same for non-fertilized treatments	2	24,8	19,0	3,7	25,0	5,0	20
Same for fertilized treatments	4	27,8	20,0	6,7	29,7	5,9	30
Content of P ₂ O ₅ in extract, in % of amount	6	70	53	75	63	—	—
Amount of fertilized treatments, in % of supply of non-fertil.	—	112	105	181	119	118	—
Coefficient of correlation between amounts of available and soluble phosphates	—	0,96±0,14	0,88±0,24	0,86±0,26	0,86±0,26	—	—

Note: Comma represents decimal point.

According to this, using Kirsanov's method, the fertilized chernozems also are amply provided with phosphates. According to the lactate method, they fall in the group of being fully and medium provided with phosphates. Regrettably, fully dependable indices are not available. Therefore, the verification of the limit is the current problem in the field experiments with phosphate application.

Data on the amount of soluble phosphates remaining in the extracts expressed in percent of the total amount are important in characterizing the different chemical methods. The amount of phosphate remaining in the extract depends on the soil group and on the method of preparation of the extract (Table 2). On the fertilized treatments they were 2%-3% and sometimes 5%-7% greater than on the non-fertilized. This attests to the fact that fertilizer application not only increases the amount of soluble phosphates, but weakens the fixation of phosphates by the soil.

Simple comparison of the results of the chemical method with the effectiveness of phosphates in the experiment does not give complete information on the suitability of the method for evaluating the amount of phosphates in the soil. In the field experiments phosphate effectiveness was determined not only by the contents of the available phosphates, but also by other conditions. The assimilation of phosphates by plants in the experiments could be increased without increasing the yield. The phosphate extracted from the soil by the plant constitutes only part of the available phosphates. Finally, when the extracts are made there is a secondary precipitation of phosphates, and in consequence the content of phosphorus in the extract does not give the correct value of the amount of soluble phosphates in the soil.

The determination of the amount of soluble and available phosphates permits obtaining of a comparative value which more fully characterizes the relation of the plant, as well as the reagent, to the phosphates in the soil.

To evaluate the suitability of chemical methods of determining the amount of phosphates in the soil which are available to the plants, the coefficients of correlation between the amounts of available and soluble phosphates were determined. The computation of coefficients of correlation were carried out by the formula

$$m_r = \frac{\sqrt{1-r^2}}{\sqrt{n-2}}$$

which is used with a limited number of observations (3).

All the coefficients of correlation for the four methods on the leached and thick chernozems have a high degree of significance, up to 0.01 according to Fisher's table (3). This attests to the fact that they are in principal all suitable for the analyses of these soil groups.

Lower levels of significance, 0.05, were obtained by the Chirikov and Egner methods on gray forest clay loam. On the carbonate chernozem the lower significance of the coefficient was obtained by the three methods of Chirikov, Egner, and Kirsanov; on the podzolized soils the two methods of Kirsanov and Egner gave the

lower significance. The methods of Truog and Chirikov resulted in no reliable coefficients.

With a high degree of correlation between the amount of soluble and available phosphates in the soil, it is possible to compute coefficients of regression which, on the basis of the chemical analyses data, make it possible to determine the amount of available phosphates in the soil.

We shall show the regression equations for the northern, low humic thick chernozem. In these equations y is the amount of available phosphates and x of soluble phosphates:

1. Method of Truog $y = -6.0 + 0.58 x$
2. Method of Chirikov $y = -10.0 + 0.72 x$
3. Method of Egner $y = 3.7 + x$
4. Method of Kirsanov $y = -10.9 + 0.64 x$

A coefficient of regression of the amount of available phosphates to the amount of soluble phosphates of 1.0 was found only for the method of Egner. Considering the distribution of the amount of soluble phosphates in the extracts and in the soil, we find the following regression equations between the available phosphate (y) and the content of P_2O_5 in the extracts (z).

1. Method of Truog $y = -6.0 + 0.78 z$
2. Method of Chirikov $y = -10 + 1.24 z$
3. Method of Egner $y = -3.7 + 1.42 z$
4. Method of Kirsanov $y = -10.9 + 1.08 z$

The regression equations for amounts of soluble and available phosphates are applicable only for a given range of values for specific conditions. The foregoing equations were obtained for a small number of cases and therefore are only good for orientation. The mere possibility of obtaining an approximate biological quantitative evaluation by a chemical method shows the need for further work in this direction.

The values obtained with the chemical methods of Kirsanov, Truog, and Chirikov are higher than those obtained with the pot experiment; the values obtained with Egner's method are almost always lower than those obtained by the pot experiment. The amount of soluble phosphate obtained by Chirikov's and Truog's methods are identical (except for carbonate soil). The values of the extracts differ substantially because the secondary precipitation of the phosphates and the acetic acid extract by Chirikov's method is correspondingly higher than in the sulfuric acid extract by Truog's method. Apparently both methods determine the same group of phosphates in a given soil. Kirsanov's method gives higher values of soluble phosphates than the methods of Truog and Chirikov. Egner's method is interesting in that it indicates clear differences between plots which received fertilizer and those that did not receive it. The values for fertilized plots according to this method are two to four times greater than for those which did not receive fertilizer. This method is most suitable for identifying phosphated soils, i.e., soils that were enriched with phosphates by fertilizer application. This method gives close agreement on absolute values with those obtained by pots. Undoubtedly, on chernozem non-carbonate soil this method deserves considerable attention. The values of Egner's method for fertilized and non-fertilized treatments prove that the amount of soluble

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phosphates as well as the amount of available phosphates on fertilized treatments are quantitatively better and have greater availability.

Conclusions

1. Systematic application of fertilizer in usual practical quantities on leached and thick chernozems in the sugar beet zone leads to a strong accumulation of available and easily soluble phosphates.
2. The process of enrichment of the soil with available phosphates when fertilizer is applied is expressed by a quantitative increase of the amount of available phosphates as well as by the change of their quality, that is, an increase in the degree of their availability.
3. The amounts of soluble phosphates determined by the use of radioactive tracers for the Truog and Chirikov methods are identical. Apparently these methods extract the same group from non-carbonate soils. For the methods of Kirsanov the supply of soluble phosphates is somewhat higher than for the Chirikov and Truog methods. For the lactate method it is somewhat smaller.
4. The amount of available phosphate determined by pot experiments is considerably lower than the amount of soluble phosphates determined by means of radioactive tracers (for the methods of Kirsanov, Chirikov, and Truog).
5. Egner's method gives values of soluble

phosphates somewhat lower than those of available phosphates, determined in the pot experiment. The values of Egner are particularly good to indicate fertilized phosphated soils.

6. For leached chernozems, thick chernozems, and for northern low humic thick chernozems a high, and a completely reliable correlation was obtained for the values of the amount of available phosphates (chemical methods of Truog, Chirikov, and Kirsanov). This points to the possibility of using chemical methods for these soils.

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NEW METHODS OF STUDYING SOIL MICROORGANISM ASSOCIATIONS

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In studying natural groups of microorganisms, the investigator must, in the laboratory experiment, reproduce as nearly as possible the natural conditions under which they develop.

According to modern concepts, the main mass of soil microorganisms lives at the surface of soil particles and only an insignificant amount is found in a suspended state in soil solutions. This fact, which was experimentally substantiated by Novogrudskiy (6), is also stressed by Khudyakov (17), who points out that liquid media are unsuitable for the study of the soil microflora.

However, not only liquid, but also the majority of solid media used at present do not correspond at all to the conditions under which microorganisms develop in nature. Laboratory media usually contain a much larger amount of nutrients than is contained in soil solutions which wash over soil particles. In addition, they contain no components of humus, which are always present in varying amounts in every soil.

Agarized soil extracts, various synthetic media, and media with humates, which had been proposed by various authors (19, 4 and others) for determining autochthonous bacteria have not been greatly used. At the same time, all soils contain a wide group of microorganisms which are incapable of developing on standard nutrient media and consequently are systematically eliminated from the view of the investigator.

Soil microorganisms live mostly in colloidal films of organo-mineral gels of humic substances which cover the elements of the mineral skeleton of soil. This is the reason why solid media containing humus most closely corresponds to conditions under which microorganisms develop in soil.

As we know, humic substances are chemically heterogeneous. In different soil groups different forms of humic substances predominate (16, 10, 3). Fulvic acids predominate in soils of the podzolic zone, their quantity often exceeding that of humic acids 2-3 times (16) and sometimes even 3-5 times (10). Humic acids are represented by brown humic or by so-called ulmic acids.

Humic acids accumulate in the soil in an un-

dissolved state, and in the form of the gels of their complicated, complex compounds with the mineral elements of the soil. The nature of the organo-mineral compounds of soil humus changes from south to north as a result of the impoverishment of soils in bases. If the main role in the fixation of humus in chernozems is played by calcium, with closer proximity to the north the role of this element is gradually replaced by iron and aluminum (12, 11).

When studying the transformations of humic substances in soils of one or another zone, it is imperative that such forms be used in the experiment which are most characteristic for the given conditions. This is why we feel that sodium humates, which are often used for this purpose, are hardly suitable for such a type of investigation. They are not found in normally moist and excessively wet soils, and partially characterize only the humus of saline soils.

The predominating forms of humus in the soils of the podzolic zone are the organo-mineral complexes of fulvic and ulmic acids with sesquioxides, which we used in our work.¹

To obtain organo-mineral complex humic acid compounds we used hydrochloric acid and alkaline (0.1-N solution of NaOH) soil extracts. The sequence of the procedure for the preparation of the compounds of fulvic acids from acid extracts has been described in detail in our previous work (1).

As we know, ulmic and fulvic acids are extracted from the soil simultaneously by alkaline solutions. These substances can be separated through a method of preparation. We experimented on three types of organo-mineral complexes: 1) those formed by fulvic acids, 2) those formed by ulmic acids, and 3) those formed by both humic acids together. The method of obtaining them was the following. Ulmic acids were precipitated from the alkaline extract (obtained from the accumulative horizon of a peat-podzolic soil) by means of hydrochloric acid and, after removing the fulvic acids remaining in the solution by filtration, they were dissolved again in 0.10 N

¹ These substances were separated according to the method of Ponomareva and under her constant consultation, for which the authors are very grateful to her.

alkali. The alkaline solution was carefully acidified to a pH of 3.5 and a small amount (from a few drops to several milliliters) of a ferric chloride solution was added to it until ulmic acids had been completely separated in the precipitate. After filtration, salts were carefully removed by washing until there was no reaction for the chloride ion in the filtrate. The gel was then removed from the filter and was ground in a mortar with a little water to form a homogeneous consistency, after which it could serve as a nutrient substrate for the microorganisms.

Fulvic acids remaining in the filtrate were precipitated by bringing the pH of the solution to about 6.0. After filtration, washing, and trituration, the preparation was used for microbiological experiments. Organo-mineral compounds containing all humic acids were prepared by the same method used to obtain the ulmic acid gel, except that fulvic acids were not previously removed.

No matter how chemically close the obtained compounds are to the natural forms of humic substances, the following must be remembered when using them as nutrient substrates for microorganisms. The conditions of development of microorganisms in a Petri dish or test tube, even in very selective media, are still different from their conditions of development in nature.

In the soil the microorganisms are at the surface of particles which border on narrow soil capillaries in which soil moisture and air circulate continuously. Because of this, their entire activity takes place under conditions of continuous circulation and renewal of the medium. These conditions are absent in a dish. Natural conditions may be simulated more closely by using growth glasses according to the method of Rybalkina and Kononenko (13, 14, 15). The use of this method made it possible for the authors to determine the natural groups of microorganisms typical for various soils and led to the important conclusion that a distinction must be made between the active and the potential soil microflora.

Intending to investigate the microflora of soil in its natural habitat, we used somewhat different methods.

Great possibilities for reproducing natural conditions are offered by a new device, the capillary pedoscope of B. V. Perfil'yev and D. R. Gabe.² Considering subaqueous soil materials, muds, and soils as open capillary systems, Perfil'yev developed an original method making it possible to study the microflora in these systems under conditions close to those found in nature. He suggested the use of a set of thin, rectangular glass capillaries with plane-parallel walls. When these capillaries are placed in the soil, or mud, a physical-chemical circulation regime establishes itself rapidly in the capillaries, which is close to that of the surrounding medium, and the corresponding micro-

flora begins to develop. The glass walls of the capillaries, simulating mineral soil particles, do not interfere with the microscopic examination of developing coenoses under any magnification of the microscope. By means of the capillary method, Perfil'yev discovered in mud and soil materials a large number of unusual genera, (not yet described), and species of microorganisms with very interesting physiological characteristics. In particular, he discovered a new biological group of predatory bacteria (7, 8).

The capillary pedoscope we used consists of a set of capillary cells with five-way capillaries, mounted in a glass holder. The pedoscope is inserted in the soil by means of a metal puncher, which protects the fragile walls of the device from breaking.

To reproduce natural conditions as closely as possible, we filled the capillaries with the organo-mineral gel of humic substances before placing the pedoscopes into the soil, which was then immediately removed with hygroscopic cotton, or by drying at room temperature. As a result, the inner surface of the capillaries was coated with a thin film of humus and therefore could serve as a model for soil particles. Part of the capillaries was then filled with water, while the other part remained filled with air. The pedoscopes were placed in various soils under natural conditions, or in soil contained in greenhouse pots. In addition, "live monoliths" were used, collected by the Perfil'yev method, which is the following. The soil sample, together with the plants growing on it, is cut with a metal rectangular greenhouse pot, lined with glass, without disturbing the genetic horizons. One of the side-walls is removable, so that the pedoscope can be placed in any genetic horizon. The monoliths are kept moist.

The field and laboratory experiments were conducted on the same soils. These soils were generally virgin soils from the isthmus of Kareliya: surface-podzolized soil, iron-podzol, humic-iron podzol, and crypto-podzolic soil. A few observations were also made on cultivated podzolic soil.

The pedoscopes were set into the A and B horizons and were kept there from a period of 10-12 days to 2-3 months. After they were removed from the soil, the microgrowths on the walls of the capillaries were examined under the microscope, first in a live state and then after fixation of the sample and after it had been stained with erythrosine.

By means of the capillary pedoscopes data may be obtained on the distribution of microorganisms in the soil studied, their natural forms of development and predominating groups, the relative number of the individual components of coenosis, and the biological relationship and interrelationships existing between them. In setting the pedoscopes near the roots of plants, one may obtain an idea of the interrelationship between micro- and macro-organisms as members of a single coenosis.

However, the method of direct observation of microorganisms in nature is not all-inclusive and must be supplemented by other methods. The

²For a detailed description of the device, see the article of D. R. Gabe in the same issue of this journal.

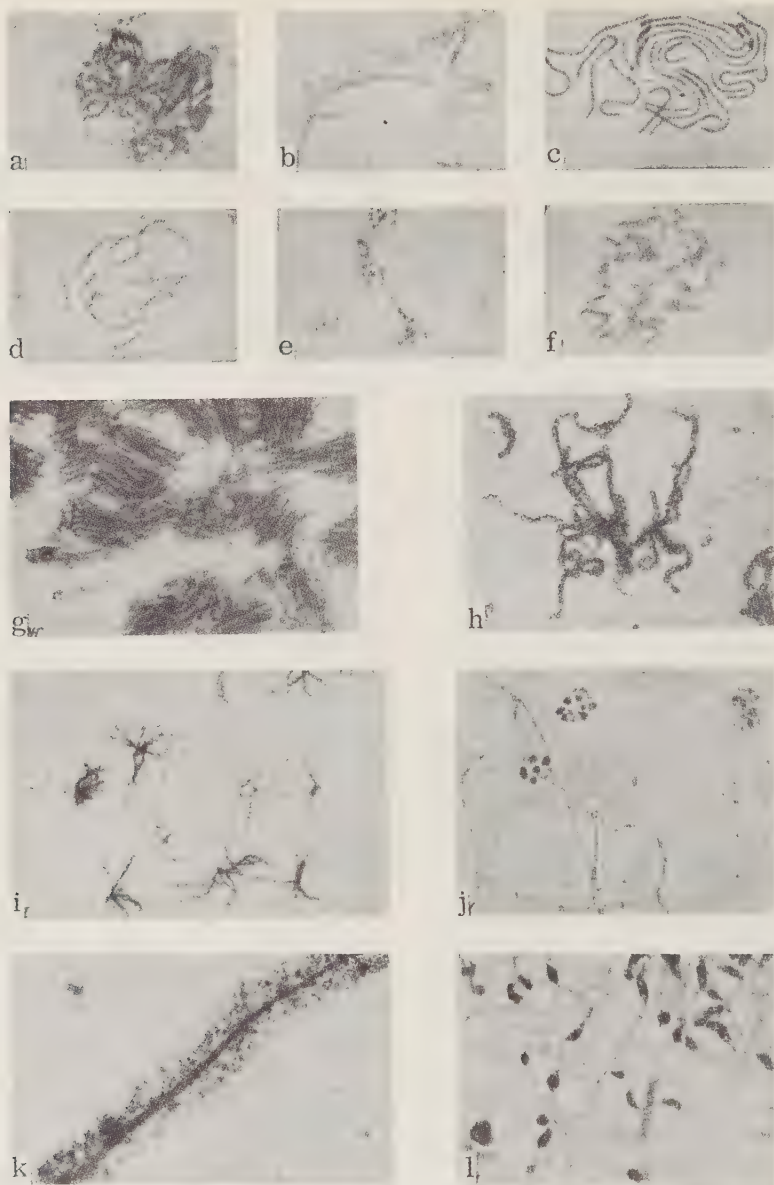


Fig. 1. - Nature of the development of microorganisms on organo-mineral films of humic substances.

a,b,c,d,e,f,g - bacteria, magnified 1500 times; h,k - fungi, magnified 170 times; i - actinomycetes, magnified 170 times; l - development of etallogenium on fungus hyphae, magnified 170 times; m - structure of the organism Pedomicrobium, magnified 1500 times.

species composition of developing microorganisms, the nature of their life activity, and their role in the process of soil formation cannot be determined by this method. To solve this problem, laboratory experiments are necessary. By inoculating solid nutrient media containing organo-mineral compounds of soil humus with the soil studied, and by comparing the microorganisms developing on them with the bacterial growths in pedoscopes, one can sub-

stantially supplement the results of observations in nature.

As nutrient media we used agarized media containing organo-mineral compounds of humic substances. In preparing them, gels of humic acids were mixed with a large amount of water and after bringing the pH of the mixture to 6.5-7.0, 1.5%-2.0% agar-agar was added to it. The media were sterilized for half an hour at a

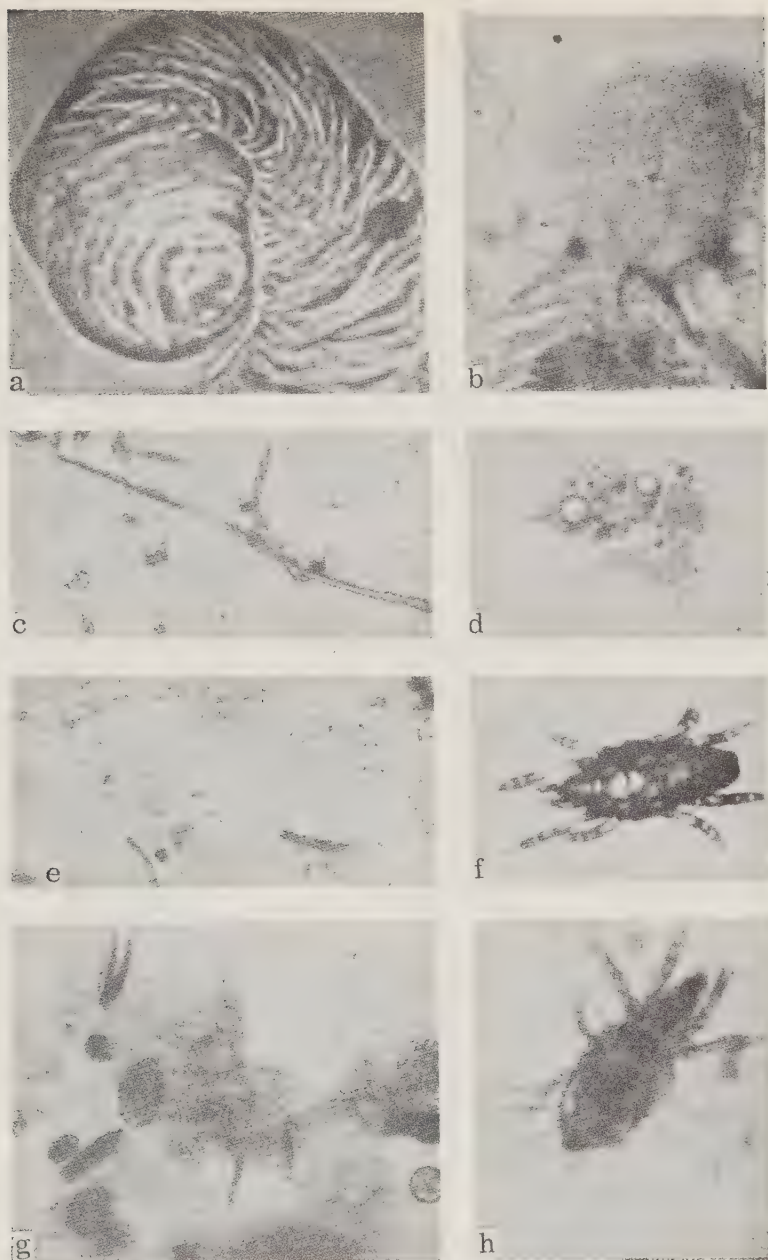


Fig. 2. - Development of microorganisms and representatives of the soil fauna.

a - trace of a mobile colony of bacteria on an organo-mineral gel of humic substances, magnified 70 times; b - mobile colony of bacteria, magnified 280 times; c,e - antagonism of bacteria and fungi, magnified 1500 times; d - soil amoeba in a capillary of the pedoscope, magnified about 1500 times; Representatives of soil mites: f - Trombidiformes, magnified about 200 times; h - Tyrophagus noxius magnified about 200 times; g - empty shells of an egg and an egg of Tyrophagus noxius.

pressure of 0.5 atm. Inoculation was achieved by the deep method in Petri dishes. In certain cases the sterile organo-mineral gel was applied together with the inoculated material to the sur-

face of agarized water in a Petri dish.

The microorganisms developing on specific solid media may be identified and studied



Fig. 3. - Interrelationships between soil microflora and microfauna.

a - egg of the mite *Trombidiformes* attached to the mycelium of actinomycetes, magnified 170 times; b - predatory fungus *Verticillium*, magnified 170 times; c,d - contamination of a mite by the mycelium and spores of a predatory fungus; e,f - soil nematode caught by a predatory fungus, magnified 170 times; g - interwoven fungus hypha remaining after the victim had been destroyed, magnified 170 times; e,h - destruction of a mite caught by the mycelium of a predatory fungus, magnified 170 times.

physiologically. This is very important for determining more precisely the principles relating the individual members of the coenosis to each other and for learning about their role in soils.

It must be noted, however, that in spite of the high selectivity of the media used, the microflora developing on them is not fully identical with the growth of microflora in capillaries.

First of all, the quantitative relationship between the individual species in the dishes and in the capillaries differ. Certain microorganisms which predominate in the pedoscopes do not develop at all on agarized media. In particular, we could not produce bacteria in the culture which form characteristic balls of long, twisting rods in the capillaries (see Fig. 1, a, b, c), often found in the B horizon of humic-illuvial soils under conditions of adequate moisture. These twisting formations vary in size and apparently belong, not to one, but to several species of bacteria, the nature of which is yet unclear.

In other cases the simultaneous use of the capillary method with the method of inoculating soil suspensions on solid media with humic acids leads to more fruitful results and permits one to find phenomena which escape the microbiologist who uses standard methods of investigation.

Since this article is of a methodological nature, we will not describe the soils studied and the comparative characteristics of their microflora in detail, because it will be the subject of a special article. Our task now is to show, by a few examples, the possibilities of the new methodological approach to studying soil microorganisms.

The peculiarity of the substrates we used (independent of whether they are applied to the walls of capillaries or are placed in Petri dishes) is that not only a diversified microflora, but also a diversified microfauna, (consisting of protozoa, primarily ameba and small invertebrate animal, primarily mites and nematodes [Fig. 2, d, e]), develop on them.

Under these conditions, fungi and bacteria do not form large, rapidly increasing colonies, which are so typical for common laboratory media. On agarized media containing humic acids, the bacteria grow primarily in the form of microcolonies, nidus accumulations of cells (Fig. 1, d, e, f, g). Only in certain cases do they form very small colonies, still visible to the naked eye. In the capillaries one can see only nidus accumulations and microcolonies, generally consisting of not more than a few tens of cells.

Mold fungi and actinomyces do not form solid mycelium cushions on solid media nor in the channels of pedoscopes, but develop in the form of individual mats or scattered, short hypha with sporangia (Fig. 1, h, i, k). This corresponds to the natural forms of development of microorganisms described by Novogradskiy (5), and proves the closeness of the media used to natural substrates.

A characteristic feature of the microscopic population of organo-mineral films is the large amount of sessile and creeping forms of microorganisms. As we know, mold fungi and actinomyces lead a sessile form of life. However, the more typical inhabitants of the organo-mineral gels used are new microorganisms discovered by us (species *Pedomicrobium* n. gen. Arist.), which were previously unknown in spite of their ubiquity in our soils.

The species *Pedomicrobium*, (to which a

special article will be devoted), possesses the ability of decomposing organo-mineral complexes of humic substances with sesquioxides. In doing this, iron and manganese hydroxides are accumulated. On solid media with humic acids they form very small iron or manganese colonies, slowly increasing in size, and resembling actinomyces colonies in form. After dissolving the iron and manganese deposits, which mask the structure of the cells, with hydrochloric or oxalic acid, one may find circular, oval, or rod-shaped, elongated cells, connected to each other by thin, branching threads (Fig. 1, m). *Pedomicrobium* multiplies primarily by budding. Usually, up to 4 branching threads grow from a cell, at the ends of which a single gemma, or daughter cell, forms. As they grow in size, the daughter cells in turn give forth branching threads.

Since the morphological and physiological characteristics of the species *Pedomicrobium* are described elsewhere, we will not examine the properties of this interesting microorganism now; we will say only that it is represented by two forms in the soils studied. One of these, *Pedomicrobium ferrugineum* Arist., primarily accumulates iron, while the other, *Pedomicrobium manganicum* Arist., accumulates manganese.

Since these microorganisms take part in the modification of the specific organo-mineral substances of the soil, they undoubtedly play an important role in soil formation.

Under laboratory conditions the microorganisms develop most prolifically on media with organo-mineral compounds of fulvic acids. Their colonies appear somewhat later and develop more slowly on media with ulmic acid. We were not able to grow them on nutrient media devoid of specific forms of humic substances. This probably explains why such a widespread microorganism in our soils had not been discovered previously.

In addition to *Pedomicrobium* colonies, another microorganism, *Metallogenium* Perf., which has not yet been described in the soil literature, appears on media with ulmic acid in very small colonies, visible only through a magnifying glass. This organism, which accumulates manganese primarily, was discovered and first described by Perfil'yev (8, 9). Since its structure is masked by manganese deposits and partially by iron, *Metallogenium* remained unnoticed. It was discovered and thoroughly studied only when the method of capillary microscopy was used. Living in mud, *Metallogenium* is of great geological importance as an ore-forming organism. It undoubtedly plays an important role in soils, even though it is found less frequently than *Pedomicrobium*. Apparently, its development on media is associated with the development of mold fungi. The main mass of manganese colonies of *Metallogenium* is usually found near fungus hyphae, and it sometimes develops directly on hyphae, forming unusual growths (Fig. 1, l).

Among the microorganisms creeping on the substrate, mobile colonies of bacteria, plus numerous protozoa and small invertebrates deserve attention. Occasionally, when inoculated material and the organo-mineral gel of fulvic acids are applied to agarized water, small curved furrows of unusual form appear at the surface of the gel.

Although these may be taken for the traces of small animals, under closer examination it is obvious that they are the traces of mobile colonies of bacteria. Such colonies consist of rather thin, slightly curved rods which are in a state of slow alternating-rotating motion like the motion of colonies of *Bac. rotans*, or *Bac. migrans*. The forward edge of the rotating colony is usually curved, while the back of the colony is elongated in the form of a tail (Fig. 2, b). Boring themselves into the organo-mineral gel, these colonies leave a long-lasting spiral trace, slightly resembling a snail in form (Fig. 2, a). Mobile colonies appear most often on such gels of organo-mineral complexes of fulvic acids and sesquioxides in which the mineral portion strongly predominates over the organic portion.

Using our media it is difficult to obtain pure cultures of microorganisms developing on them by inoculating individual colonies. The magnitude of mobile forms of bacteria, protozoa, and invertebrates leads to the rapid contamination of the colonies by foreign bacteria and fungi. On the one hand this presents certain difficulties in work, but on the other hand it allows observation of the interrelationships between the individual components of coenosis not only in capillaries, but also in mixed cultures, which is impossible when using standard methods of investigation. At the same time, following the instructions of Vinogradskiy (2), who called for the study of the microbial situation in soil and for the investigation of microorganisms in their natural habitat, account must be taken of the whole complex of the complicated interrelationships developing between the individual members of the biocoenosis. Generally, microbiologists who study the microbial population of soils, limit their objectives to the study of bacteria, mold fungi and actinomycetes. They do not attempt to clarify the interrelationships existing between the microflora and the microfauna. This problem is usually examined only in special works, devoted to individual problems (for instance, the study of predatory fungi with the object of controlling soil nematodes) which do not have as a goal the investigation of soil microcoenoses as a whole. The works of Novogradskiy (5), and Shilova (18), in which relationships are established between bacteria, protozoa, and soil invertebrates, are noteworthy.

Making our observations by the method of capillary microscopy and supplementing them with the study of mixed cultures on our solid media, we discovered several types of biological relationships existing between the microscopically small inhabitants of the soils studied. One of these we have already mentioned in speaking of the characteristics of growth of *Metallogenium* near the fungal mycelium. In addition, an antagonism between mold fungi and bacteria is often evident (especially in examining the capillaries). The bacteria are located along fungal hyphae and gradually dissolve them (Fig. 2, c). The final result is that instead of mycelium threads, only bacterial cells are left, which retain their initial position along the disappeared hyphae (Fig. 2, e). An analogous picture of the lysis of fungal hyphae under the influence of bacteria was observed by Rybalkina and Kononenko (14) on growth glasses.

Of special interest are the relationships between microorganisms and small invertebrates. We found a large number of mites in the soils studied. V.I. Volgin, the chief scientific member of the Parasitology Branch of the Zoological Institute of the Academy of Sciences of the USSR, determined them at our request. The mites most frequently found on our substrates were representatives of the family Tyroglyphidae (species *Tyrophagus noxius* As.) (Fig. 2, h) and Trombidiformes (Fig. 2, f). Some of them (Trombidiformes) feed primarily on fungi, while others (Tyroglyphidae) feed also on bacteria and the dead organic substrate. One may often observe unusual "pastures" under the microscope, consisting of fungi and bacteria on which tens of mites sometimes feed. Trombidiformes break off the sporangia of the fungi with their mouths and Tyroglyphidae devour the bodies of bacteria and the nutrient agar. On these "pastures" the mites deposit their eggs. Tyroglyphidae do this directly on agar, often near bacterial colonies, or even right in the bacterial colonies. Certain colonies are literally "stuffed" with the eggs of mites. After the larvae hatch from the eggs, their empty shells resemble the open shell of an Anodont mollusk (Fig. 2, g). Trombidiformes attach their eggs to the mycelium mats of molds or actinomycetes; there were no eggs deposited simply on agar. Apparently this was a primitive display of unusual care for the young. First of all, by being attached to the threads of the mycelium the eggs are protected from being carried away into the lower soil horizons by soil water. In addition, the larva hatched from the egg can immediately find its food. The photograph in Figure 3, a, shows the eggs of the mites, empty of larvae, as they are attached to the mycelium of actinomycetes. In addition to fungi, which serve as the preferred food of mites, there are predatory fungi throughout the soils studied, which apparently belong to the genus *Verticillium*. The mycelium of this fungus resembles barbed wire (Fig. 3, b), on the barbs of which sit slimy heads with spores. Moving along the substrate, the small invertebrates catch on the sticky heads, which become attached to their bodies (Fig. 3, c, d).

If the animal has enough force to free itself, it tears off part of the mycelium, or only the head with spores, and carries it with it. Later the fungus grows in the cells of the animal and causes its destruction (Fig. 3, e, h). In certain cases the fungus succeeds in retaining its victim in place (Fig. 3, f). The nematode shown on the photograph was alive at the time of photography, but a little more than one day later there was no trace left of it. Mites last much longer because of their strong chitinous skeleton.

Finally, only an unusual net, consisting of interweaving fungus hyphae (Fig. 3, g), remains in the place of the destroyed and digested victim.

The foregoing examples illustrate clearly enough the new possibilities of this method used for discovering the still unknown aspects in the soil life. The microflora, which becomes apparent with such an approach, differs sharply from the microflora found by standard methods of soil microbiology. A considerable place is occupied in it by new microorganisms which have not yet been described in the literature, as well as bacteria, formerly unknown as inhabitants of the soil. The number of new forms discovered

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by us is not limited to the *Pedomicrobium* genus. At least two more new microorganisms, which we obtained in cultures, are widespread in the soils examined, and are now being studied.

A great advantage of the method we used is its certain universality, that is, its suitability for the study of not only the microflora, but also the microfauna. This is very valuable for conducting complex investigations. Complex investigations do not lead often to noticeable results because of the absence of a unified methodological approach to the solutions of problems by specialists in various fields of biology. They divide the whole unit—biocoenoses of soil—into individual parts, depending on their scientific competence. As a result, the existing natural relationships among organisms remain undisclosed.

Conclusions

1. The microbial associations in several soils of the isthmus of Kareliya were studied by means of capillary pedoscopes of Perfil'yev and Gabe and by inoculating soil suspensions on solid nutrient media of humic acids. To reproduce better natural conditions, thin films of gels of organo-mineral complexes of humic acids with sesquioxides were applied to the inner surface of the walls of capillaries before placing them in the soil. The same substances were used in the preparation of nutrient media for parallel cultures in Petri dishes.

2. New, widespread genera of microorganisms were discovered in the soils studied, which decompose the complex compounds of humic substances and accumulate iron and manganese.

3. The inhabitants of organo-mineral films are primarily sessile and creeping forms of microorganisms, protozoa (mainly amoebae) and small invertebrate animals (mites and nematodes).

4. The method used makes it possible not only to determine the characteristics of the qualitative composition of natural microcoenoses, but also to discover the biological relations existing among individual organisms. Interrelationships between certain fungi and bacteria, mites, fungi, and bacteria, as well as fungi and nematodes have been established.

5. The use of the capillary pedoscope (which is described in detail in the article by D. R. Gabe) in conjunction with solid nutrient media, containing humus, may be recommended for conducting complex investigations on the biology of soil.

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GRAY FOREST SOILS OF THE KRASNOYARSK FOREST STEPPE AND CERTAIN PROBLEMS OF THEIR GENESIS

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In Siberia the forest steppe zone occurs in the form of "islands" and is not as continuous as that of the European USSR. The Krasnoyarsk forest steppe is one of such forest steppe "islands" of Siberia, and is located on the left bank of the Yenisey River, north of Krasnoyarsk, and occupies a gently rolling piedmont plain. In the east, south, and southwest it borders on ancient mountain systems (Yenisey Ridge, Eastern Sayan, and the Kemchug uplands), while in the north and northwest it is open to the West Siberian lowland.

The plain gradually slopes from south to north. The absolute elevations of the watershed vary from 340 m to 180 m in a distance of 200 km from south to north, and the flood plains of the Yenisey River, from 145-116 m.

The major soils of the forest steppe are gray forest soils in combination with leached chernozems. Their distribution is closely related to the relief. As a rule, gray forest soils develop in areas with rolling hills and on gently rolling watersheds, while leached chernozems develop at the foot of the hills and on river terraces.

The soils of the Krasnoyarsk forest steppe have been studied little. In 1912 Blagoveshchenskiy (2), a soil scientist of the Immigration Board, investigated this area. His report gives a general scheme of the distribution of the major soil groups of the area. A brief mention of the soils of the area is found in the work of Nikolayev (12). The agricultural properties of soil and certain problems of their genesis are discussed briefly in the works of Petrov (13), Gorshenin (5), and Kolyago (7).

The gray forest soils of the Krasnoyarsk forest steppe develop in birch and birch-pine (sometimes mixed with aspen) forests. The remains of large pine and larch stumps indicate that in the near past these trees played an important role.

The forests of the Krasnoyarsk forest steppe are characterized by a well-developed, dense and tall (40-50 cm) herbaceous cover with Calamagrostis arundinaceae, Trollius asiaticus, Thalictrum minus, Galium boreale, Pulsatilla flavescens, Sanguisorba officinalis, Chamaenerium angustifolium, Geranium coeruleum, Lathyrus gmelini, and others.

The forests alternate with meadow steppe areas, where mixed herbage is represented by Pulsatilla flavescens, Libanotis intermedia, Thalictrum minus, Dracocephalum ruyschiana, Iris ruthenica, and others. Phleum phleoides, Avena Schelliana, and Poa pratensis predominate among grasses.

The parent materials on which gray forest soils develop are represented primarily by friable Quaternary clay deposits of deluvial, or eluvial-deluvial origin. The clay is often sandy at the summits of high hills and is often underlain by sandy-gravelly deposits of a Lower Quaternary age 1-3 m thick. In the southern part of the region, red Devonian deposits (Kachin suite), represented by marl, sandstone, and limestone, come close to the surface; the clay deposits overlying them are enriched with iron and are of a red-brown color. Residual type carbonate content is characteristic of all soil-forming parent materials.

The climate of the forest steppe is continental, moderately humid. The mean annual temperature varies from +0.3°C (Krasnoyarsk) to -1.7°C (Great Murta village). The mean monthly temperature in January is -20.8°C and that in July, 17.8°C. The frost-free period lasts 85-120 days, and the number of days with a temperature of >0°C is 102-110, i.e., 1.5-2 months shorter than in the forest steppe zone of the European USSR. The sum of >10°C temperatures is 1500°-1600°C, while in the forest steppe zone of the European USSR (Tula and Ryazan' Oblasts) it is considerably higher (2200°-2300°C).

Mean annual precipitation is 360-380 mm, varying from 320-400 mm from year to year. The annual precipitation distribution is uneven, a considerable part (120-130 mm) falling in July-August. In winter (December-March) snow precipitation averages only 41-46 mm, which is unevenly distributed in the area as a result of wind. In treeless areas the snow is blown away from open areas and deposited in depressions. The soil, which is almost bare of snow, freezes to a great depth (down to 3.6 m) with the low winter temperatures, and fissures. The soil does not freeze as deeply in the more forested areas (north and west), where snow is distributed more evenly. The depth of soil freezing reaches 2 m here.

Because they freeze to a great depth, the soils thaw late, which noticeably affects their

hydrothermal regime and microbiological life. The soils thaw completely in the poorly forested part of the forest steppe in August, and in the more forested part, by the end of June. Thus a frozen layer remains for a long time at a certain depth in the soils (at a greater depth in the southern, less forested part, than in the northern) (4). The presence of this layer, which acts as a condenser and conservator of moisture, leads to the formation at a depth of 150-220 cm of a very moist (90%-100% of minimum water capacity) layer, with the existence of which seasonal gleization is associated. Signs of gleization at a depth of more than 100 cm are found in all soils of the forest steppe.

According to the amount of humus, the thickness of the humus layer, and the degree of podzolization, we divide the gray forest soils into dark-gray, gray, and light gray.

The degree of podzolization of the soils is closely related to geomorphological conditions and to the elevation and dissection of the relief. Strongly podzolized soils are found on the higher and dissected watersheds and their slopes, while slightly podzolized soils are found in the lower parts of slopes, or on low and slightly dissected watersheds. Apparently this is associated with the rate of leaching; it is faster under conditions of high and dissected relief than in depressed and slightly dissected areas. In addition to the decisive role of geomorphological conditions, there are other factors that may have an important influence, such as the two-layer texture of the material at a depth of 1.5-2 m, and also general climatic variations and the increase in moisture from east to west.

The morphological profile, as generally in all gray forest soils, is characterized by three horizons: a humus-accumulative horizon (A_1), an eluvial horizon ($A_1 A_2$), and an illuvial horizon (B). The differentiation of the soil profile is closely associated with the degree of podzolization of the soils: it is weak in slightly podzolized dark-gray forest soils and very pronounced in strongly podzolized light-gray soils.

The characteristic morphological features of the gray forest soils of the Krasnoyarsk forest steppe are: 1) the high humus content of the shallow (0-10 cm) humus-accumulative A_1 horizon; 2) the high degree of removal of Ca and Mg carbonates, which are usually found at a depth below 1.5-2 m and sometimes at 4 m; and 3) the presence of signs of gleization in the profile of most gray forest soils at a depth below 80-100 cm, which is determined by their hydrothermal regime. The degree to which signs of gleization manifest themselves differs and depends on the drainage of the area and the ice content of the frozen layer associated with it.

Below we give a description of the conditions of deposition and morphological indices of typical profiles of gray forest soils.

Profile 77. Light-gray, a strongly podzolized forest soil. The profile was taken 2 km to the south of Tyzhnovka village at the summit of a narrow hill (absolute elevation, 350 m) under a mixed pine-birch forest with a thin mixed grass vegetation. The parent material is brown,

slightly sandy clay with occasional gravel. Carbonates are found from a depth of 140 cm.

A_0 0-1 cm. Needle and leaf litter.

A_1 0-9 cm. Dark-gray (ashes) to a depth of 3 cm, lower is gray with light-gray spots, damp, interwoven with grass roots, unstably-granular, fine clay loam below. Transition to lower horizon is definite in color and structure.

$A_1 A_2$ 9-20 cm. Light-gray, powdered white, granular-nutty medium clay loam, slightly compact. The transition is clear in color, structure, and compactness.

B 20-50 cm. Brown with a cinnamon-brown tinge, moist, clay, compact, stably nutty structure. The transition is gradual.

BC 50-80 cm. Slightly lighter in color than the preceding, compact, sticky, of a prismatic-coarse nutty structure; small rust spots appear from a depth of 70 cm.

C 80-140 cm. Same brown, sticky, compact clay with small rust spots.

CK 140-220 cm. Brown clay with fine gravel, becomes more sandy with depth, carbonates are in the form of small mealy spots. Does not effervesce.

Profile 9. Gray, moderately podzolized forest soil. The profile was taken at the summit of a flat hill under a pine-birch forest with dense herbaceous vegetation. The vegetation is mixed herbaceous with a large amount of meadowrue, anemone, peavine, aconite, etc. Does not effervesce to a depth of 160 cm.

A_1 0-12 cm. Dark-gray, moist, densely riddled with roots, granular, fine clay loam. The transition is gradual.

$A_1 A_2$ 12-22 cm. Gray-brown with a faint whitish tinge, moist, granular, fine clay loam. The transition is noticeable.

B_1 22-40 cm. Brown, moist, compact, clay, finely nutty. The transition is gradual.

B_2 40-68 cm. Brown, moist, compact, nutty. The transition is gradual.

BC 68-120 cm. Grayish-brown, compact, sticky clay with rust spots, becoming sandy with depth.

C 120-160 cm. Same clay, but more sandy.

Profile 6. Dark-gray, slightly podzolized forest soil. The profile was taken on the gentle slope of a hill under a mixed birch-pine forest with very sparse underbrush. Sparse mixed-herb grass vegetation. Reedgrass, fern, iris, golden thoroughwax, meadowrue, forest geranium, burnet, etc., predominate. The parent material is loess-like coarse clay. Signs of gleization are found from a depth of 100 cm. Effervesces from a depth of 170 cm.

A_0 0-3 cm. Slightly decomposed litter of needles and leaves.

A₁ 3-16 cm. Dark-gray with a whitish tinge when dry, granular, full of rootlets, compact because of the roots, medium clay loam. The transition is gradual.

A₂ 16-30 cm. Gray-brown with humus tongues, slightly moist, granular-nutty, with a whitish powder on the faces of structural units, compact. The transition is gradual.

B 30-70 cm. Brown with a faint chocolate tinge, moist, sticky, fine clay loam with occasional gravel, nutty, compact. The transition is noticeable.

BC 70-170 cm. Lighter and drier than the preceding, compact, porous, clay, with signs of gleization from a depth of 100 cm; specks of manganese, small rust spots; carbonates from a depth of 170 cm in the form of small spots. Effervesces along carbonate inclusions.

Chemical analyses (Table 1) point to a high content of humus (6.5%-11%) in the A₁ horizon. This makes these soils similar to the gray forest soils of the Kuznetsk and Mariinsk forest steppe, where the humus content also is high and varies from 7%-14%, but makes them different from the European (Central Russian) gray forest soils, which contain less humus (2%-8%, rarely reaching 10%) (18). Such an intense accumulation of humus can be explained by changes in the conditions of mineralization of organic substances with the increase in the continentality of the climate from west to east.

As may be seen from the results of chemical analyses, the accumulation of organic substances is limited, primarily to the layer at 0-10 (15) cm; the humus content sharply decreases with depth, which is especially noticeable in strongly and moderately podzolized soils (Profiles 77, 342, and 9) and makes them similar to sod-podzolic soils. The depth of the humus profile is insignificant, a humus content of more than 1% usually is found only to a depth of 40-50 cm.

The results of an analysis of the qualitative composition of humus in a gray, moderately podzolized forest soil (Profile 9), made according to the Tyurin method (17), are given in Table 2.

A group of humic acids predominates in the group composition of humus in the upper A₁ horizon of gray forest soils under natural vegetation. The ratio of humic to fulvic acids is >1, which indicates that the sod process of soil formation predominates. This ratio narrows sharply with depth, becoming <1. The latter better characterizes the humus composition during podzol formation.

Available data on the analysis of the group composition of humus in the gray forest soils of European USSR (1, 8, 10, 16) indicate that the humic acid:fulvic acid ratio widens with depth, as a rule.

Attention is drawn to the fact that in the group of humic acids in the upper horizons the fraction associated with Ca (fraction II) predominates, and not the fraction of newly-formed humic acids (ulmic acids) (fraction I), as in the case

for the majority of gray forest soils of the European USSR. Fraction I comprises only 14%-19% of the total amount of humic acids, making the soils studied similar to soils of the chernozem group.

The variations of the qualitative composition of humus along the profile of these soils also exhibit a certain peculiarity. A comparative increase of humic acids, which is associated with Ca, does not occur in the B horizon, as pointed out by a number of authors dealing with the gray forest soils of European USSR.

The fractions of fulvic acids in the soil studies have common features with European soils as far as their qualitative composition is concerned, such as the predominance of fulvic acids of fraction I in the upper horizon and the accumulation of fraction Ia in the B horizon, which is combined with mobile sesquioxide hydrates. According to literature data, the presence of this fraction is characteristic for the process of podzol formation.

Thus, the results of the analysis of the humus of these soils points to their unusualness, as expressed in the presence of indices common both to the sod and podzol processes.

Judging by pH determinations (Table 1), the acidity of the upper horizons of the soils studied is close to neutral, or is neutral (Profile 6). It increases along the profile depending on the degree of podzolization of the soils, except in Profile 342, where the reaction varies little, in spite of considerable podzolization. The B and BC horizons are characterized by the highest acidity. Acidity is primarily due to aluminum. The uppermost horizon retains its close-to-neutral reaction, independent of the podzolization of soils, which is apparently attributable to the neutralizing effect of bases which are released during the decomposition of plant litter.

Data on exchangeable acidity (adsorbed hydrogen, according to Gedroyts, and hydrogen and aluminum according to Sokolov) indicates its almost complete absence along the soil profile. A certain insignificant increase of it with depth can be noted in the more podzolized soils (Profiles 77 and 9). The absolute values, however, are very insignificant. The saturation of the adsorption complex with bases is 97%-99%. Hydrolytic acidity does not exceed 2 meq/100 g of soil.

The rather high acidity of the illuvial horizon, together with a high degree of saturation, apparently can be explained by the presence of the fraction Ia of fulvic acids, which retain their acid reaction even in the presence of large amounts of the Ca(HCO₃)₂ in solution (10).

The sum of adsorbed bases in horizons close to the parent material is high, varying from 29-37 meq/100 g of soil. Calcium predominates in the composition of adsorbed cations with 72%-85%, while the magnesium content is 15%-27%.

Soil-formation processes lead to a change in the amount and partially the composition of adsorbed bases along the profile. The sum of adsorbed bases in the humus-accumulative horizon reaches 40 meq, in dark-gray and gray, slightly

Table 1
Physicochemical characteristics of gray forest soils

Depth cm	Hygro- scopic moisture in %	Humus (accord. to Tyurin)	pH		CO, %	Adsorbed cations, meq/ 100 g of soil				Content of adsorbed cations in % of total				Adsorption capacity, meq/ 100 g of soil	Exchangeable acidity, meq/ 100 g of soil (by Sokolov)		Hydrolytic acidity in meq/ 100 g of soil	Clay >0.001 mm diameter	Sum of <0.01 mm diameter
			water	saline		Ca ⁺⁺	Mg ⁺⁺	Na ⁺	H ⁺	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	H ⁺		H ⁺	Al ⁺⁺⁺			
Light-gray forest soil. Profile 77.																			
0-10	4.68	8.74	6.8	5.8	Not det'd.	26.7	4.3	Trace	Not det'd.	31,086,113.9	—	—	Not det'd.	Not det'd.	Not det'd.	21	43		
10-20	3.03	2.18	6.3	5.6	"	11.3	3.0	"	det'd.	14,379,020.9	—	—	det'd.	"	"	18	42		
22-32	5.53	1.41	5.8	5.1	"	25.7	7.3	"	1.1	34,175,424.3	—	—	3.2	"	"	36	55		
45-55	7.70	1.29	5.3	4.6	"	24.3	8.3	"	1.9	34,570,424.1	—	—	5.5	"	"	46	63		
83-90	6.91	0.80	5.4	4.0	"	26.3	7.9	"	0.2	34,476,523.0	—	—	0.5	"	"	41	61		
120-130	7.19	0.48	6.2	5.6	"	28.7	8.5	0.5	Not det'd.	37,776,122.5	1.3	1.3	Not det'd.	"	"	43	63		
140-170	6.64	Not det'd.	6.4	5.8	Trace	30.0	9.3	0.5	det'd.	39,875,323.3	1.3	1.3	det'd.	"	"	40	59		
190-205	6.10	det'd.	6.8	5.8	"									"	"	37	53		
Profile 342 ^a																			
0-7	2.65	6.57	6.7	6.0	None	22.2	3.8	Not det'd.	0.1	26,185,114.6	Not det'd.	Not det'd.	0.3	0.06	0.09	15	34		
7-17	2.06	2.21	6.9	6.4	"	12.9	2.3	det'd.	0.1	15,384,315.1	Not det'd.	0.6	0.06	0.04	1.23	16	36		
35-42	4.81	0.84	6.4	4.9	"	19.1	5.9	"	0.1	25,476,423.0	"	0.3	0.06	0.11	0.81	35	51		
70-80	4.72	0.59	6.1	4.7	"	20.7	5.5	"	0.1	26,378,720.9	"	0.3	"	0.11	1.52	31	48		
130-140	4.85	Not det'd.	6.8	5.3	"	22.7	5.1	"	0.1	27,951,318.3	"	0.3	"	0.20	1.36	34	52		
190-210	5.62	det'd.	7.1	6.3	Trace	30.3	4.8	"	Not det'd.	35,186,413.5	Not det'd.	Not det'd.	Not det'd.	None	0.94	Not det'd.	det'd.		
210-220	5.33	"	7.5	7.0	3.73						28.6			0.09		39	57		
230-240	2.96	"	7.6	7.1	1.56						22.4			0.06	Not det'd.	Not det'd.	Not det'd.		
Gray forest soil. Profile 9 ^a																			
0-12	3.86	7.26	6.5	5.4	Not det'd.	27.8	4.5	Trace	0.3	32,485,313.8	Trace	Trace	0.9	0.09	0.06	32	49		
12-22	4.67	2.71	5.8	4.8	"	18.4	6.6	0.5	0.8	26,570,024.8	2.2	2.2	3.0	0.07	0.10	39	57		
22-30	5.33	1.92	5.3	4.2	"	20.8	6.1	0.5	1.1	28,573,321.7	1.2	1.2	3.8	0.09	0.28	45	58		
30-40	5.73	1.80	5.1	4.1	"	24.9	7.2	0.5	1.1	33,773,824.3	1.4	1.4	3.2	0.10	0.33	46	63		
50-60	6.75	1.10	4.9	4.2	"	27.9	9.3	0.5	1.2	38,971,723.9	1.3	1.3	3.1	0.14	0.21	49	68		
85-95	6.96	1.04	5.0	4.4	"	28.4	9.3	0.5	0.3	38,573,724.1	1.3	1.3	0.8	0.01	0.02	46	66		
120-140	7.64	0.40	5.8	5.6	None	22.0	8.8	0.5	0.2	31,569,828.1	1.5	1.5	0.6	Not det'd.		39	61		
140-160	5.75	0.36	6.1	6.0	"	22.2	8.4	0.5	0.1	31,351,226.9	1.5	1.5	0.3	Not det'd.	Not det'd.	22	41		

^a Analyzed by: L. A. Bulayeva, N. A. Kamennykh, G. G. Rusakova, and N. A. Tyapkina.

Note: Comma represents decimal point.

Table 1 (continued)

Table 1 (continued)																			
Depth cm	Hygro- scopic moisture in %	pH		CO ₂	Adsorbed cations, meq/ 100 g of soil				Content of adsorbed cations in % of total				Adsorption capacity, meq/ 100 g of soil	Exchangeable acidity, meq/ 100 g of soil (by Sokolov)		Hydrolytic acidity in meq/ 100 g of soil	Clay <0.001 mm diameter	Sum of <0.01 mm diameter	
		water	saline		Cs ⁺⁺	Mg ⁺⁺	Na ⁺	H ⁺	Ca ⁺⁺	Mg ⁺⁺	Na ⁺	H ⁺		Al ⁺⁺⁺					
Dark-gray forest soil. Profile 6 ^a																			
0-3	7.18	38.56	7.1	6.6	None	83.1	11.9	0.5	None	95.5	87.0	12.4	0.5	None	Not det'd.	2.18	27	52	
3-8	7.20	11.16	7.0	6.1	"	31.5	8.6	0.4	"	40.5	77.7	21.2	1.1	"	"	1.73	35	65	
8-16	3.56	4.73	6.6	5.6	"	27.2	4.3	Not det'd.	0.2	31.7	85.7	13.7	Not det'd.	0.5	"	2.18	35	66	
18-28	4.07	2.47	6.2	5.0	"	25.7	4.3	0.7	0.2	30.9	83.1	13.7	4.0	0.6	"	2.33	40	68	
35-45	4.57	1.31	6.2	4.9	"	26.3	4.4	Trace	0.2	30.9	85.0	14.2	2.0	0.7	"	2.02	42	69	
55-65	5.06	0.94	6.2	5.1	"	23.2	5.2	"	Trace	28.4	82.4	17.5	—	—	"	1.70	37	65	
80-90	4.27	0.65	6.6	5.4	"	24.6	5.2	"	"	29.8	82.9	17.1	—	—	"	1.42	38	65	
110-120	4.22	0.58	7.5	5.2	"	Not det'd.				Not det'd.				Not det'd.		Not det'd.	38	66	
135-145	4.19	0.77	6.7	5.6	"	Trace				Not det'd.				Not det'd.		Not det'd.	39	67	
160-170	4.45	0.95	7.3	6.3	0.4	30.6	4.0	Trace	Not det'd.	34.6	88.5	11.5	—	—	"	0.80	41	68	
230-245	5.91	0.72	7.4	6.4	0.7	Not det'd.				Not det'd.				33.27		Not det'd.	Not det'd.	41	61

^aAnalyzed by: L. A. Bulayeva, N. A. Kamennykh, G. G. Rusakova, and N. A. Tyapkina

Table 2

Group composition of humus in gray forest soils, in % of soil weight (numerator), and in % of total content of carbon (denominator). Profile 9.

Depth cm	Total content of carbon, %	Wax- resin	Soluble in 1.0-N Na ₂ SO ₄	Fractions of humic acids				Fractions of fulvic acids				Total	Hydrolysis of 0.5- 1.0-N H ₂ SO ₄	Insoluble residue	Ratio of humic to fulvic acids
				I	II	III	Total	I a	f	II	III				
0-12	4.22	0.18	0.13	0.22	0.56	0.36	1.14	0.05	0.34	0.18	0.36	0.93	0.23	1.67	1.46
12-22	1.40	4.26	3.08	5.21	13.27	8.52	27.08	1.18	8.08	4.24	4.97	18.47	5.45	39.57	0.81
		0.07	0.05	0.04	0.16	0.07	0.27	0.08	0.03	0.18	0.14	0.33	0.05	0.61	
50-60	0.67	5.00	3.57	2.85	11.45	4.99	19.29	5.71	2.86	12.14	2.86	23.57	3.57	43.53	0.47
		0.03	0.04	None	0.06	0.01	9.07	0.07	0.01	0.07	Trace	0.15	0.02	0.33	
		4.47	5.97		8.95	1.43	10.38	10.44	1.50	10.44		22.38	2.98	49.25	

Note: Comma represents decimal point.

Table 3
Results of the total chemical analysis of gray forests soils, in % of ignited soil

Depth, cm	Hygroscopic moist., %	Ignition losses, %	SiO ₂	R ₂ O	Fe ₂ O ₃	Al ₂ O ₃	TiO ₂	P ₂ O ₅	CaO	MgO	MnO	Na ₂ O	K ₂ O	SO ₃	SiO ₂ /Al ₂ O ₃	SiO ₂ /Fe ₂ O ₃	SiO ₂ /R ₂ O ₃
Light-gray strongly podzolized forest soil. Profile 77.																	
0-10	4.68	13.08	77.44	16.24	1.77	14.47	Not det'd.	0.16	1.59	1.16	Not det'd.	0.74	1.15	0.06	9.21	129.0	8.60
10-20	3.03	3.23	77.99	16.89	1.68	15.21	0.02	0.10	0.10	1.18	0.06	1.62	1.98	Trace	8.66	130.0	8.12
22-32	5.53	3.17	71.97	22.13	2.90	19.23	0.06	1.29	1.38	1.38	"	1.32	1.89	0.04	6.26	59.5	5.66
45-55	7.70	4.70	68.94	24.69	5.51	19.18	"	0.06	1.09	1.61	"	0.45	1.65	0.10	6.00	38.00	5.48
120-130	7.19	3.55	69.90	23.57	3.11	20.46	"	0.01	1.51	1.60	"	0.57	2.05	0.04	5.80	58.00	5.27
195-205	6.10	4.29	70.43	24.08	5.09	18.98	"	Not det'd.	1.27	2.05	"	Not det'd.	Not det'd.	0.04	6.15	39.00	5.31
Dark-gray, slightly podzolized forest soil. Profile 6 ^a																	
3-8	3.43	10.39	69.07	23.18	7.05	14.97	0.90	0.24	2.02	2.34	0.17	1.42	2.14	0.59	7.66	28.75	6.05
8-16	3.31	8.62	69.41	23.53	6.90	15.53	1.05	0.15	1.98	2.16	0.16	1.46	1.46	0.14	7.73	29.00	6.10
18-28	3.55	6.60	68.43	25.25	7.51	16.67	0.97	0.20	1.69	2.43	0.16	0.86	1.33	0.15	7.42	24.78	5.42
55-65	3.56	4.00	66.91	25.37	7.49	16.63	1.08	0.17	1.91	2.68	0.16	1.01	1.19	0.23	6.93	24.13	5.28
80-90	3.71	4.88	67.29	25.12	8.62	15.27	1.08	0.15	1.66	2.56	0.16	1.00	1.09	0.10	7.46	22.40	5.60
160-170	3.81	5.29	67.07	25.08	7.06	16.84	1.02	0.16	1.92	2.69	0.16	1.07	1.49	0.07	6.93	27.77	5.55

^a Analyzed by K. Ya. Dorokhova.

Note: Comma represents decimal point.

podzolized forests soils, which, even though it is insignificant, exceeds the capacity of the parent material. The accumulation of adsorbed bases occurs by biological accumulation, which fully compensates for the simultaneous removal of adsorbed bases. The adsorption complex of the upper horizon in the more podzolized gray and light-gray forest soils is destroyed to a great extent, and in spite of active biological accumulation its magnitude remains smaller than in the parent material.

The amount of adsorbed cations noticeably decreases with depth along the profile. There is a clear zone of intense removal of adsorbed bases in the eluvial horizon (10-12 cm thick) of the more podzolized soils; removal also occurs in the B horizon, but it is very weak, since the accumulation of clay in it increases the adsorption capacity considerably.

The results of particle-size analysis of the soils studied show that the soil-forming parent material consists of coarse, silty clays and fine clay loams (Profile 342). They are more sandy in the soils in Profiles 77 and 342. The parent material in all horizons exhibits a poorly defined two-layered material; the slight increase in the coarseness of the parent material with depth is associated with the characteristics of its genesis (deluvial deposition). Since the two-layered material in the parent material appears weakly within the soil profile and at a considerable depth (1.5 m), apparently it has little influence on the soil-formation process.

The results of particle-size analysis for all soils studied indicates that the clay fraction (<0.001 mm in diameter) is being removed from the upper part of the profile; however, removal varies quantitatively. The highest removal of clay (about 50%) as compared to the parent material occurs in light-gray soils (Profiles 77 and 342), and the least, in dark-gray forest soils (about 11%).

It must be noted that the removal of the clay fraction in all the soils studied takes place from the surface, the same as it does in typical podzolic soils. There is almost no accumulation of clay, which should have taken place as a result of the considerable accumulation of organic substances in the upper humus horizon. Also, it must be noted that the removal of clay occurs in a shallow layer of the soil profile, while at the same time the illuvial horizon is very deep (it is very difficult to determine its lower boundary because of the heterogeneity of the parent material). It is possible that these horizons are additionally enriched with clay because of gleization.

Strongly podzolized light-gray forest soils are distinguished by a sharp change in texture at the boundary between the podzolic and illuvial horizons, which makes them similar to sod-podzolic soils.

The results of the total chemical analysis of the soils studied correlate very well with the results of other analyses and clearly show signs of podzolization in these soils. Table 3 shows that a considerable amount of silica accumulates in the upper horizons of the soils as a result of the removal of the other oxides, mainly sesquioxides

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Table 4

Results of the total chemical analysis of the clay fraction of light-gray, strongly podzolized forest soil (Profile 77), in % of ignited soil^a

Depth, cm	Hygroscopic moisture	Ignition loss	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	R ₂ O ₃	CaO	MgO	SiO ₂ / Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃	SiO ₂ / R ₂ O ₃
	%										
0—10	5,86	18,76	62,05	26,14	6,65	32,80	0,21	2,25	3,96	24,79	3,47
10—20	7,56	11,38	57,13	28,02	10,30	38,33	0,29	2,58	3,42	14,85	2,78
22—32	9,64	10,78	56,54	28,49	11,05	39,54	0,29	2,44	3,34	13,61	2,68
5—55	10,28	8,49	55,86	28,48	11,43	39,91	0,30	2,50	3,30	12,91	2,62
120—130	10,14	9,78	57,06	27,89	10,98	38,88	0,94	2,73	3,42	13,78	2,76
135—205	10,50	8,56	57,33	28,32	9,90	38,23	0,70	2,58	3,44	15,79	2,81

^aAnalyzed by N. A. Andreyeva.

Note: Comma represents decimal point.

from the upper part of the profile.

The greatest removal of sesquioxides occurs primarily in light-gray forest soils (Profile 77), which is confirmed by the change in molecular ratios along the profile.

Iron is most intensely removed among the sesquioxides. Primarily CaO, MgO, and P₂O₅ accumulate biologically in the upper horizons. However, their absolute contents are insignificant.

The total composition of the clay fraction (Profile 77, Table 4) shows that the chemical composition of clay changes along the profile, following the changes in the total composition of the entire soil, that is, the upper part of the profile becomes poor in sesquioxides (primarily Fe₂O₃) and rich in silicic acid. Such a phenomenon can be explained by the decomposition of clay and the differential removal of the decomposition products, i.e., podzolization.

The results of micromorphological investigations of light-gray forest soil (Profile 77) correlate well with the results of chemical analyses. The humus horizon (0-10 cm) differs from the lower-lying horizons by its cinnamon-brownish-brown color. The clayey part of this horizon does not react to polarized light, which indicates that the humus is isotropic and that the group of humic acids predominates in the composition of humic acids in this horizon.

Thin sections clearly show signs of leaching, characteristic of podzolic soils. Areas poor in clays and rich in sandy-silty particles are clearly visible in the layer at 10-22 cm. A small number of tongues of mobile clays of a reddish-brown color also appear at this level, which increases noticeably with depth. This clay fills small pores and lines the walls of large pores and cracks in the form of laminated and shelly incrustations. In contrast to the main mass of clay, this clay does not contain sandy-silty particles and has a banded structure under crossed nichols, when fresh. The nature of these clays is not fully clear at this time.

The incrustations of mobile clay are found at a shallow depth, and there are few at a depth of 130 cm.

Thus, as analyses show, the gray forest soils of the Krasnoyarsk forest steppe are characterized by an intense accumulation of humus and adsorbed bases in the A₁ horizon, a close to neutral reaction of the solution in the same horizon, an almost complete base saturation in the adsorption complex (95%-99%) throughout the profile, and the predominance of humic over fulvic acids in the A₁ horizon. All this serves as evidence of a contemporary active sod process in these soils.

However, such signs as the removal of clay and R₂O₃ from the upper horizons and the decomposition of the adsorption complex (especially in light-gray forest soils) is in contradiction with the evidence of a contemporary sod process (the close-to neutral reaction of the medium and the base saturation of the adsorption complex). We are inclined to explain this controversy by past podzolization, of which the foregoing signs remain at present.

The problem of the genesis and evolution of gray forest soils in the Krasnoyarsk forest steppe cannot be considered as fully solved on the basis of data available at present. The earliest phases of the development of these soils are not sufficiently clear. They can be surmised only on the basis of paleogeographical data (11, 14, 15). The latter indicate that the steppe landscapes occupied larger areas in the region of our studies than at present in the middle of the post-glacial period, because of a drier and warmer climate. As a result of subsequent cooling and a more humid climate at the beginning of historical times, a displacement of landscape zones occurred to the south, and forests took possession of part of the steppe areas. The degradation of steppe soils and their podzolization occurred under the influence of the advance of forests into the steppe. These positions confirm the hypothesis of S. I. Korzhinskiy of the formation of slightly podzolized soils in the forest steppe via the degradation of chernozems. At the same time the possibility is not excluded that strongly podzolized soils in

the forest steppe formed initially under the forest, the preceding stage being soil of the sod-carbonate group. The long development of the latter soils in the forest is evidenced, in addition to podzolization, by the concentration of organic substances in the upper, shallow horizon and its sharp decrease with depth, the predominance of fulvic over humic acids in the sub-humus horizon, and the deep leaching of carbonates.

At the present time a weakening of podzol formation and an intensification of the sod process take place as a result of the increasing mildness and warming of the climate (19), observed in the past century, and also because of man's activity. Consequently, a progradation of formerly more podzolized soils takes place now in the soils studied, which is expressed in the accumulation of humus and bases associated with it. The high base saturation of our soils is attributable to the accumulation of bases. The process of progradation is most pronounced in light-gray and gray, strongly and moderately, podzolized soils.

The progradation process is not inherent only to the gray forest soils of the Krasnoyarsk forest steppe, but it also takes place in more westerly areas, such as the Mariinsk (7-9) and Kuznetsk (6) Oblasts, as well as in more easterly areas, such as the Kansk forest steppe (Budina and Vishnevskaya [3]), and apparently is associated with the change in bioclimatic conditions over wide areas.

Conclusions

1. The gray forest soils of the Krasnoyarsk forest steppe, in addition to having the characteristics of soils of this group, also have regional peculiarities, such as a high humus content, deep leaching of carbonates, signs of seasonal gleization (associated with the persistence of a frozen layer in the lower part of the profile).

2. The problems of the genesis and evolution of gray forest soils in the Krasnoyarsk forest steppe are not solved yet. This is attributable not only to the fact that they have been studied little, but also to the complicated historical development of these soils.

The various ways of their development are being examined (Korzhinский and Dokuchayev). Gray, slightly podzolized forest soils probably developed as a result of the degradation of steppe soils; strongly podzolized steppe soils formed most likely in the forest. These differences in genesis can be found at the present time and are expressed in the differences in the properties of gray forest soils.

3. Progradation processes take place at the present time in all gray forest soils.

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INFLUENCE OF EXCHANGEABLE H^+ , Al^{+++} , AND Na^+ ON THE AVAILABILITY OF SOIL PHOSPHORUS AND PHOSPHORITE TO PLANTS

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Organic ion exchange resins, which were first synthesized in 1935, rapidly found use in scientific investigations, including agricultural chemistry. Because of its adsorption-exchange properties, ion exchange resins may serve to a certain degree as a model of the adsorption complex of soil. Many investigations dealing with the problem of plant nutrition, using ion exchange resins saturated with various ions, studied their role as a source of nutrients for plants. The literature on this problem was summarized by Peterburgskiy (7) and Hewitt (17).

We used ion exchange resins in our work to study the role of exchangeable H^+ , Al^{+++} , and Na^+ in the decomposition of phosphorite, and also in the mobilization of phosphates in the soil proper.

The effectiveness of ground phosphorite is associated with the presence of exchangeable hydrogen (hydronium) and aluminum in the soil, which determines the acidity of the soil (1, 3, 4, 6, 8). A suggestion was made that the uptake of ground phosphorite by plants increases in soil containing exchangeable sodium (12, 16). A critical review of the literature on this problem was given in the works of Askinazi (2) and Dmitrenko (5).

To study the influence of exchangeable cations on the decomposition of phosphorite, the investigators used soils saturated with cations from solutions of various salts. However, the saturation of soils with exchangeable hydrogen (hydronium) was achieved with weak acid solutions. The soil consists of various minerals and organic and organo-mineral substances. Therefore, it was difficult to determine the effect of individual cations on the decomposition of phosphorite by this method. In particular, the treatment of soil with acids leads to its saturation not only with exchangeable hydrogen, but also with aluminum. The latter occurred in the studies of Sokolov (14) on the influence of the pH of soils unsaturated with bases, and of their adsorption capacity on the availability of phosphorite to plants. This is why the problem of the influence of exchangeable H^+ , Al^{+++} , and Na^+ on the decomposition of phosphorite requires further study.

Using ion exchange resin saturated with various cations we had the opportunity, in contrast to work done earlier, to determine the effect of

only one cation (H^+ or Al^{+++} , or Na^+) on the decomposition of phosphorite and solubility of soil phosphates. As a source of exchangeable cations we used the monofunctional, highly acid, cationite KU-2, the active sulfo group capable of dissociating exchangeable cations into the outer solution within a wide range of pH. The properties and characteristics of exchange resins are described in detail in the works of Pashkov and Titov (9), and Saldadze (11).

To remove impurities, the cationite was first treated with a 5% HCl solution and then washed of the excess reagent with distilled water until the Cl^- disappeared from the filtrate. Then the cationite was dried at room temperature and ground until the particle size was <0.5 mm in diameter. Individual portions of the ground cationite were saturated with H^+ from a 5% solution of HCl, with Al^{+++} from a 0.1-M solution of $Al_2(SO_4)_3 \cdot 18H_2O$ (pH = 2), and with Na^+ from a 0.1-N solution of $NaCl + CH_3COONa \cdot 3H_2O$ (pH = 6.6). After being fully saturated with the foregoing ions, the cationites were washed of the excess reagent with distilled water. The adsorption capacity of H^- , Al^- , and Na^- -cationites was determined by the successive displacement of the corresponding ion from the cationite samples. The H^+ were displaced from the cationite by Ca^{++} from a 0.1-N solution of $CaCl_2$ (pH = 5.9); Al^{+++} , by K^+ from a 1-N solution of KCl (pH = 6); and Na^+ , by NH_4^+ from a 1-N solution of CH_3COONH_4 (pH = 7).

The content of hydrogen ions in the H-cationite was determined by titrating the filtrate with a 0.1-N solution of NaOH in the presence of phenolphthalein. The content of aluminum ions in the Al-cationite was determined by the method of Sokolov (13). In this case the filtrate was titrated twice: the first portion with a 0.1-N solution of NaOH with phenolphthalein and the second portion with the same solution, but in the presence of NaF. The results of titration indicated the practically complete absence of H^+ in the Al-cationite. The content of sodium ions in the Na-cationite was determined in a flame photometer. The adsorption capacity of the KU-2 cationite with respect to H^+ , Al^{+++} , and Na^+ was approximately equal and averaged 350 meq/100 g of the dry cationite. The cationites prepared in this manner served as sources of H^+ , Al^{+++} , and Na^+ in pot and laboratory experiments.

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Table 1

Chemical characteristics of chernozem used in pot experiments

Soil	Available phosphorus in mg P ₂ O ₅ , determined by the methods of		Adsorbed cations, meq		Hydrolytic acidity (with a coefficient of 1.75), meq	pH of the soil suspension	
	Chirikov, 0.5-N solu- tion of CH ₃ COOH	Truog, 0.002-N solution of H ₂ SO ₄	Ca ⁺⁺	Mg ⁺⁺		KCl	H ₂ O
	per 100 g of air-dry soil						
Thick chernozem from the Kursk Reserva- tion	5,6	7,0	30,1	4,9	4,4	5,1	5,9
Same, from Grakov experimental field	10,2	15,6	40,5	6,3	2,0	5,9	6,4

Note: Comma represents decimal point.

Table 2

Effect of exchangeable H^+ and Al^{+++} on the availability of soil phosphorus and phosphorite to plants^a

Experimental treatments	Experimental setup	H^+ or Al^{+++} , meq/100 g of chernozem	Weight of the dry mass, g per vessel	Phosphorus taken up by plants, mg P_2O_5 per vessel		pH of soil suspension at the beginning of the experiment
				Total	including from phosphorite (by difference)	
I	NK background	—	4,6	8	—	5,7
II	H-cationite	5	10,7	25	—	4,2
III	H-cationite	10	15,3	49	—	3,0
IV	Al-cationite	5	5,4	13	—	4,9
V	Al-cationite	10	6,1	15	—	4,5
VI	Phosphorite	—	12,6	35	27	5,7
VII	Phosphorite + H-cationite	5	14,9	68	43	4,5
VIII	Phosphorite + H-cationite	10	16,6	88	39	3,9
IX	Phosphorite + Al-cationite	5	13,5	50	37	5,0
X	Phosphorite + Al-cationite	10	14,1	48	33	4,6

^aThe experimental error for the I, VI-X treatment is ± 0.5 g, for treatments II-V, ± 0.36 g.

Note: Comma represents decimal point.

Pot Experiments

Experiment I was made on thick chernozem from the Kursk Reservation. The chemical characteristics of the foregoing soil are given in Table 1. Each vessel, holding 0.7 kg of soil, was supplied with 0.175 g of N and K_2O in the form of ammonium nitrate and potassium nitrate. Samples of ground cationites containing 5 and 10 meq of H^+ or Al^{+++} per 100 g of soil, or 15%-30% of the sum of adsorbed cations in the soil, were applied to the soil against a background of NK. Altogether 35 or 70 meq of exchangeable cations were applied to each vessel. Aktyuba phosphorite was added to individual vessels against the background of the same amount of cationites in an amount of 100 mg P_2O_5 per vessel. The experiment was made with the "Orel" variety of oat and replicated twice

for the experimental treatments II-V and 3 times for the experimental treatments I, VI-X. After the experiment was complete, the yield of oat and the phosphorus used by it were assessed. The setup and results of the experiment are given in Table 2.

As may be seen from the data in Table 2, the phosphorus in chernozem was best available in the presence of the H-cationite under the experimental conditions used. The yield of oats in these treatments increases 2-3 times, and the uptake of phosphorus 3-6 times as compared to the control treatment with NK. The yield and uptake of phosphorus by the plants differed little from the control in the presence of the Al-cationite. When phosphorite was applied to the soil against the background of the H-cationite, the total uptake of

Table 3

Effect of exchangeable H^+ , Al^{+++} , and Na^+ on the availability of soil phosphorus and phosphorite to plants^a

Experimental treatments	Experimental setup	H^+ or Al^{+++} , and Na^+ , meq/100 g of chernozem	Weight of the dry mass, g per vessel	Phosphorus taken up by plants, mg P_2O_5 per vessel		pH of soil suspension at the beginning of the experiment	
				Total	including that from phosphorite (by difference)	KCl	H ₂ O
I	NK background	—	6,7	12	—	5,9	6,3
II	H-cationite	5	13,2	25	—	4,9	5,3
III	H-cationite	10	17,1	49	—	4,0	4,9
IV	Al-cationite	5	7,5	15	—	4,8	5,6
V	Al-cationite	10	8,2	18	—	4,2	5,5
VI	Na-cationite	5	7,3	12	—	5,9	6,4
VII	Na-cationite	10	8,1	14	—	5,9	6,9
VIII	Phosphorite	—	7,2	14	2	5,9	6,2
IX	Phosphorite + H-cationite	5	18,9	45	20	5,0	5,4
X	Phos. + H-cationite	10	21,2	68	19	4,1	4,8
XI	Phos. + Al-cationite	5	12,3	30	15	4,8	5,8
XII	Phos. + Al-cationite	10	14,6	38	20	4,3	5,5
XIII	Phos. + Na-cationite	5	7,6	15	1	5,9	6,5
XVI	Phos. + Na-cationite	10	8,2	17	3	5,9	6,8

^aExperimental error ± 0.62 g.

Note: Comma represents decimal point.

P_2O_5 from the soil and the phosphorite by plants was 1.5 higher on the average than in the treatment with the Al-cationite. The difference method was used to determine the quantity of phosphorus taken up by plants directly from phosphorite against the background of cationites, subtracting from the amount of P_2O_5 taken up by the plants from the soil and phosphorite the amount of P_2O_5 adsorbed by the plants under the same experimental conditions from one soil only. It was found that the plants took up 39-43 mg of P_2O_5 from the phosphorite per vessel against the background of the H-cationite, and 33-37 mg P_2O_5 against the background of the Al-

cationite.

Analogous results were obtained in pot experiment II, made the next year. The experiment was made on sand-soil cultures. Each vessel was filled with 0.5 kg of thick chernozem from the Grakov experimental field and 0.7 kg of sand. The chemical characteristics of the chernozem are given in Table 1. Nitrogen and potassium (0.25 g each of N and K_2O) in the form of ammonium and potassium nitrate were used as a background. Ground samples of cationites containing 5 and 10 meq of H^+ , Al^{+++} , and Na^+ per 100 g, or 10% and 20% of the total adsorbed cations in soil,

Table 4

Effect of exchangeable Na^+ , H^+ , and Al^{+++} on the solubility of phosphorite

Experimental setup	Entered the solution from the sample		pH of equilibrium solution
	mg P_2O_5	in % of sample taken	
Phos. without cationite	0,06	0,6	6,3
Phosphorite + Na-cationite	1,0	10	6,8
Phos. + H-cationite	9,8	98	2,5
Phosphorite + Al-cationite	0,19	1,9	4,0

Note: Comma represents decimal point.

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Table 5

Displacement of phosphorus precipitated by the Al-cationite by a 1-N solution of NH_4F

Experimental setup	Mg P_2O_5 found in the solution	pH of the equilibrium solution
Phosphorite without the Al-cationite	0,2	8,2
Phosphorite + Al-cationite	5,4	8,3

Note: Comma represents decimal point.

were applied to the soil against this background. Altogether, 25 or 50 meq of exchangeable cations were applied to each vessel.

Yegor'yev phosphorite was added to individual vessels against the background of the same amount of cationites in an amount of 100 mg of P_2O_5 per vessel. The experiment was made with "Dunne" oats and replicated twice. The data given in Table 3 show that, as in the preceding experiment, soil phosphorus was taken up with a great intensity by the plants against the H-cationite background. However, the amount of phosphorus taken up by plants against the Al-cationite background did not differ from that in the control with NK. The amounts of phosphorus removed by plants from phosphorite, which were applied to the soil both with the H-cationite and the Al-cationite, were very close. According to calculations by the difference method, the plants took up about 20% of P_2O_5 of the 100 mg applied to the vessels in both versions of the experiment.

It must be noted, however, that the difference

Table 6

Passage into solution of phosphorus from the Al-cationite after its interaction with phosphorite

Experimental setup	Water solution		1-N solution of NH_4F	
	Mg P_2O_5 removed from the sample	pH	Mg P_2O_5 removed from the Al-cation.	pH
Phosphorite without Al-cationite	0,08	6,4	—	—
Phosphorite + Al-cationite	0,21	4,2	6,45	3,2

Note: Comma represents decimal point.

method does not always give the correct presentation about the uptake of phosphorus by the plants from the soil and fertilizers (15). Therefore, it would be desirable to use phosphorite with tagged phosphorus in the experiments to determine the ability of plants to take up phosphorus from phosphorite in the presence of hydrogen or aluminum ions.

It follows further from Table 3 that the presence in the soil of exchangeable sodium in amounts of 10% and 20% of the total amount of adsorbed cations had almost no effect on the uptake of soil phosphorus and phosphorite by plants. The data obtained correspond with the results of pot experiments made by Golubeva (4), Ratner (10), and the field experiments of Dmitrenko (5). They do not confirm the point of view of Smirnov (12), and Tolochko (16), who believe that the decomposition of phosphorite may occur under the

Table 7

Comparative data on the ability of Al- and H-cationites to decompose phosphorite

Experimental setup	H^+ or Al^{+++} meq	Water solution		0.5-N solution of NH_4F		Aqua regia solution
		Mg P_2O_5 removed from the sample	pH	Mg P_2O_5 removed from Al-cation.	pH	Mg P_2O_5 removed from phosphorite
Phosphorite without cationite	—	0,10	6,5	—	—	—
Phosphorite + Al-cationite	0,25	0,26	4,9	0,98	7,3	7,4
Phosphorite + Al-cationite	0,5	0,33	4,8	2,3	7,4	5,5
Phosphorite + Al-cationite	0,75	0,34	4,7	3,5	7,4	4,5
Phosphorite + Al-cationite	1,0	0,33	4,6	4,5	7,5	3,8
Phosphorite + Al-cationite	2,5	0,22	4,2	7,7	7,7	1,2
Phosphorite + Al-cationite	5,0	0,15	4,0	8,6	7,8	0,53
Phosphorite + Al-cationite	10	0,09	3,7	9,0	7,9	0,33
Phosphorite + H-cationite	0,25	6,4	4,0	—	—	—
Phosphorite + H-cationite	0,5	9,8	3,0	—	—	—
Phosphorite + H-cationite	0,75	10,2	2,7	—	—	—
Phosphorite + H-cationite	1,0	10,1	2,7	—	—	—

Note: Comma represents decimal point.

influence of exchangeable sodium.

Thus, the results of pot experiments with soil and sand-soil cultures showed the ability of exchangeable H^+ and Al^{+++} to decompose phosphorite, which was not true for the Na^+ under the same experimental conditions.

Laboratory Experiments

Experiment I. Samples of Yegor'yev phosphorite, containing 10 mg of P_2O_5 , were placed in 100-ml flasks to which 5 meq of H^+ or Al^{+++} , or Na^+ and 50 ml of water were added. The flasks were shaken for an hour and then allowed to steep for 18 hours. The pH of the equilibrium solutions was determined with a glass electrode and the phosphorous content was determined colorimetrically by the Truog-Meyyer method (Table 4).

As may be seen from Table 4, the Na-cationite decomposed phosphorite only partially; from the 10 mg P_2O_5 in the solution only 1 mg of P_2O_5 , or 10% of the sample taken, was found. In the presence of the H-cationite all the phosphorus in the phosphorite went into solution. With the interaction of the Al-cationite with the phosphorite, about 2% of the amount of phosphorus contained in the sample was found in the equilibrium solution. Such an insignificant amount of phosphorus as was found in the solution after the interaction of the Al-cationite with phosphorite in the laboratory experiment seems to contradict the results of pot experiments. In these experiments Al-cationite had a great ability to decompose phosphorite and increase the availability of phosphorus to plants. However, one may assume that under laboratory conditions two opposed processes take place when phosphorite interacts with the Al-cationite; on the one hand the decomposition of phosphorite followed by the dissolution of phosphorus, and on the other hand its subsequent precipitation by aluminum present either in the solution, or at the surface of the solid phase.

The following experiment was made to verify this assumption. A mixture of phosphorite and Al-cationite was left in the filter after interaction in the aqueous solution. It was then placed in a 100-ml flask and treated with 50 ml of 1-N NH_4F (pH = 8.3), which dissolves aluminum phosphates because of its ability to form with aluminum six-membered complexes of AlF_6^{---} . The interaction of the precipitates with the fluoride solution was achieved by constant shaking for 3 hours. After this the suspension was filtered, the pH in the filtrate was determined with a glass electrode, and the phosphorous content was determined colorimetrically. The data in Table 5 substantiated our assumption about the precipitation of phosphorus, dissolved after the decomposition of phosphorite, by Al^{+++} . Thus, after the treatment of the mixture of phosphorite and the Al-cationite with ammonium fluoride, more than 50% of phosphorus contained in the initial phosphorite sample entered into solution.

The same laboratory experiment was repeated using a somewhat different method.

Experiment II. In this experiment, as in the

preceding, 5 meq of Al^{+++} in the form of the Al-cationite were made to interact in solution with phosphorite containing 10 mg of P_2O_5 . After the interaction took place, the two components were separated in water with a sieve in such a manner that the finer phosphorite passed through the sieve, while the Al-cationite was retained. The Al-cationite, separated from phosphorite, was dried at room temperature, transferred to 100-ml flasks, and shaken, as in the preceding experiment, with 50 ml of a 1-N solution of NH_4F for 3 hours. The pH and the phosphorous content were determined in the equilibrium solution.

As may be seen from Table 6, a large amount of phosphorus, more than 60% of the amount contained in the initial sample, entered into solution after the interaction of the Al-cationite with NH_4F , which agrees with the results of the preceding laboratory experiment.

Phosphorus was determined not only in the Al-cationite fraction, but also in the phosphorite residue separated from the Al-cationite (phosphorite was decomposed with aqua regia). The results of analysis showed that the Al-cationite did not fully dissolve the phosphorite. The phosphorite residue contained 1.75 mg of P_2O_5 , or 17.5% of P_2O_5 in the sample taken. The results show that the Al-cationite has a smaller ability to dissolve phosphorite than does the H-cationite (see Table 4).

However, the uptake of phosphorus by plants (see Tables 2 and 3) from phosphorite (calculated by the difference method) was approximately the same both in the presence of the H-cationite and that of the Al-cationite in soil. This is why additional laboratory experiments were made to verify this, in which the ultimate amounts of H^+ and Al^{+++} necessary for the practically full decomposition of the phosphorite sample taken were determined.

Experiment III. Phosphorite samples, containing 10 mg of P_2O_5 , were placed in 100-ml flasks to which cationites containing from 0.25-10 meq of H^+ and Al^{+++} were added. The flasks were filled with 50 ml of water, shaken for 1 hour, then allowed to stand for 18 hours, then shaken again for 3 hours, and then allowed to stand for 2 hours. The pH in the equilibrium solutions was determined with a glass electrode and the phosphorous content was determined colorimetrically. After the Al-cationite had interacted with the phosphorite in the solution, the mixture of these components was dried on a filter at room temperature, and then the Al-cationite and the phosphorus were separated by dry sieving (the phosphorite particles were <0.15 mm in diameter, while those of the Al-cationite were >0.25 mm in diameter). The Al-cationite, separated from the phosphorite, was placed into 100-ml flasks and shaken with 50 ml of a 0.5-N solution of NH_4F (pH = 7.1) for 3 hours. The pH and phosphorous content in the equilibrium solution were determined. The phosphorite separated from the Al-cationite was decomposed in aqua regia and phosphorus was determined in the solution. The results of the experiments are given in Table 7. The data show that 0.5 meq of the H-cationite was sufficient to decompose fully a phosphorite sample containing 10 mg P_2O_5 . Under the same experimental conditions 0.5 meq of the Al-cationite removed only 2.3 mg of P_2O_5 ,

or 23% of P_2O_5 in the sample. To decompose fully the phosphorite sample with the Al^{+++} cationite, not less than 2.3 mg of the Al^{+++} were necessary, i.e., 5 times more than H^+ .

The lesser ability of Al^{+++} to decompose phosphorite as compared to the H^+ was noted by Askinazi and Yarusov (1) in pot experiments using isolated sand cultures in the presence of soil samples saturated with aluminum or hydrogen.

Thus, the results of our laboratory experiments confirmed that H^+ have a much greater ability to decompose phosphorite than Al^{+++} .

On the basis of the results of laboratory experiment III one may assume that 25-50 meq of Al^{+++} are sufficient to decompose fully a phosphorite sample containing 100 mg of P_2O_5 . About the same amounts of Al^{+++} (from 25 to 70 meq) were applied to pots together with phosphorite samples containing 100 mg of P_2O_5 in the pot experiments. This apparently explains the similar uptake of phosphorus by plants from phosphorite against the background of the H -cationite and the background of the Al -cationite under conditions of our pot experiments.

Conclusions

The following was established in pot and laboratory experiments using cationites saturated with hydrogen, aluminum, or sodium:

1. When applying a cationite containing exchangeable hydrogen or aluminum ions to soil, the uptake of phosphorus by plants from phosphorite increased.
2. The interaction of ground phosphorite with the H -cationite leads to the decomposition of phosphorite accompanied by the dissolution of phosphorus.
3. Two processes took place during the interaction of phosphorite with the Al -cationite: the decomposition of phosphorite and the dissolution of phosphorus, and its subsequent precipitation from the solution by aluminum ions.
4. The interaction of phosphorite with the Na -cationite lead only to a slight increase of the solubility of phosphorite.
5. The addition of the H -cationite to soil (thick chernozem) considerably increased the uptake of soil phosphates by plants.

6. A lesser ability of the Al -cationite to decompose phosphorite as compared to the H -cationite was established in laboratory experiments.

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SALT TRANSFORMATIONS IN THE SOILS OF IRAQ

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Irrigation, as a method of reclaiming new areas in the arid zones of the world, is drawing wide attention in relation to the growth of world population; however, its use was often accompanied with the salinization and solonchization of soils, resulting in their unproductivity.

Under favorable drainage conditions and with sufficient soil permeability, irrigation can be regulated in such a way that it would not lead to salinization. Irrigation used for centuries in Egypt was never harmful to soils. In Iraq the soils are poor at the present time and can yield only a salt-tolerant crop—barley. This condition was created after several millennia of irrigation. The soils of Mesopotamia were much more fertile 4-5 thousand years ago than at present, and enabled the country to feed a large population of a high cultural level.

The problem of soil salinization in Iraq is of great interest to specialists working on newly reclaimed, irrigated areas. The saline soils of Iraq have been known since ancient times. Archeologists found scriptures dating 19 centuries back which mention that the land became white (3).

In this article we will approach the problem of soil salinization in Iraq from the point of view of certain theories of modern chemistry (5, 9). The accumulation of salts tends toward the development of a sodium-sulfate and magnesium-sulfate type of salinization, which does not correspond to the composition of irrigation water. There is no reason to believe that the irrigation water of the Euphrates and Tigris has changed much from the beginning of irrigation (approximately 5000 years before our era) to our times. The typical composition of the waters of the Tigris is the following (in grams per liter):

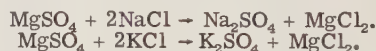
MgCO_3 —0.0484, CaSO_4 —0.0664, NaCl —0.00329
 CaCO_3 —0.00785, Na_2SO_4 —0.0093, NaNO_3 —0.0025

This water is characterized by a small sodium content and a high calcium content. Prolonged irrigation by these waters resulted in the accumulation of salts in the soil. The soils contain 16%-30% calcium carbonate, 30%-50% clay, and occasionally gypsum in the form of deposits in the deeper layers. The sodium, chloride, magnesium, and sulfate ions remaining in the soil are dissolved and thus move easily with the soil water.

The ground waters contain up to 6% salts and differ in composition from the irrigation water, which can be seen from the data given in Table 1.

Changes in the composition of ions occur in soil solutions under the influence of irrigation water, which may be seen from the data for soil samples 3 and 5, and samples of ground and drainage waters. A chloride-magnesium type of salinization is found in ground water and in soil samples, while subsoil samples show a more pronounced sulfatic salinization.

Salt transformation processes are used on a large scale in the production of potassium fertilizers, where the following salt transformations occur:



In these processes magnesium sulfate, sodium chloride, and potassium chloride are stable saline pairs. The newly-formed sodium sulfate, magnesium chloride, and potassium sulfate are unstable; they crystallize much less and thus can be easily separated. Magnesium chloride is an especially important salt which remains in the solution in the form of undissociated MgCl_2 molecules. The formation of large quantities of unstable salts as a result of the process of salt transformation is determined by factors which continuously displace the equilibrium toward the formation of such salts. This can take place in soils only when certain ions are removed from the solution by the precipitation of slightly soluble salts. It is for this reason that slightly soluble salts are of special interest in processes of salt conversions. The solubility of CaCO_3 is very low and depends on the CO_2 content in the soil solution. At low temperatures (0°C) its solubility is 0.081 g/liter and at a high temperature (30°C) it is only 0.052 g/liter.

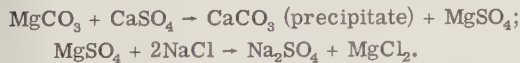
The solubility of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ is 2.65 g/l at 24°C. The presence of salts with a common ion results in the decrease of its solubility; while salts that do not have a common ion with gypsum increase its solubility (Table 2).

The solubility of magnesium carbonate becomes an important problem only when it is sufficiently high; the Mg-ion occurs in the soil solution in such an amount at which the process of salt transformation occurs, accompanied by the

formation of undissociated MgCl_2 molecules. Magnesium carbonate is considered as being a less soluble salt than calcium carbonate (limestones containing magnesium carbonate are less soluble than pure calcium carbonate rock). However, the literature gives the following data on solubility (9): $\text{CaCO}_3 - 1.2 \cdot 10^{-8}$; $\text{MgCO}_3 - 2.0 \cdot 10^{-4}$; $\text{CaSO}_4 - 6.1 \cdot 10^{-5}$.

The solubility of magnesium carbonate was thoroughly studied by American chemists (4,6). It is determined to a certain degree by the presence of $\text{Mg}(\text{OH})_2$, which has a very low solubility of $1.2 \cdot 10^{-11}$. At the normal pressure of CO_2 in water a certain amount of $\text{Mg}(\text{OH})_2$ dissolves and determines the solubility of magnesium carbonate, which is also very low. But the threshold of solubility of $\text{Mg}(\text{OH})_2$ is reached under a partial CO_2 pressure which is only slightly higher than normal. Other ions, which remove $\text{Mg}(\text{OH})_2$ from the solution, may easily increase the solubility of $\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2$, which is very low under normal conditions, and bring it up to the solubility of gypsum, for instance. It was found that the upper layers of dolomite are leached of magnesium by water containing gypsum. To show the influence of gypsum on the solubility of MgCO_3 , the following experiments were made. Normal magnesium carbonate was shaken with water with a normal CO_2 content; with this 0.072 g/liter of MgCO_3 dissolved (magnesium was determined by means of 8-hydroquinol). The reaction of this solution was alkaline. When magnesium carbonate and gypsum were shaken together the reaction became acid and 0.610 g/liter of MgCO_3 dissolved. But when magnesium carbonate and gypsum were shaken in a 5% solution of sodium chloride, the reaction became alkaline and 1.150 g/liter of MgCO_3 dissolved. With this, undissociated sodium sulfate and magnesium chloride molecules formed, which caused an increase of the solubility of magnesium.

The saline soils of Iraq, which absorb moisture from the air because of the presence of magnesium chloride in them, are widespread in the area. These soils are called "sabach" in Arabic. The formation of magnesium chloride in the soil is explained by the following salt transformations of gypsum and sodium chloride contained in the irrigation waters:



It is interesting to note that the slightly soluble salts, such as magnesium carbonate and gypsum, increased the quantity of easily soluble salts, since magnesium ions from MgCO_3 are converted to magnesium chloride, while the sulfate ions of gypsum are converted to the sodium sulfate. Thus the sulfates, together with magnesium, potassium, and, sodium chlorides, acquire a dominating role in the salinization of the soils of Iraq.

When the ground-water level rises, salinization becomes closer to the surface. This type of salinization does not develop in other areas, and the sodium-sulfate type of salinization predominates. These differences manifest themselves in the percentile composition of ions in subsoil solutions (samples 3 and 5). It is questionable why other soils do not become

Table 1

Ionic composition of soil solutions, and ground and irrigation waters

Sample No.	Sample and depth, cm	in meq/l						in % of meq					
		CO_3^{--}	SO_4^{--}	Cl^-	Ca^{++}	Mg^{++}	Na^+	Total	CO_3^{--}	SO_4^{--}	Cl^-	Ca^{++}	Mg^{++}
1	Irrigation water from the Tigris River	1,36	0,56	0,56	1,17	0,58	0,66	4,99	27,2	11,2	11,2	24,4	11,6
2	Surface soil sample No. 1037, 0-15	5,4	13,8	50,8	31,8	22,6	15,6	140,0	3,9	10,0	36,2	22,7	16,1
3	Same soil, 150-200	4,6	72,9	179,1	61,9	96,3	98,0	512,8	0,9	14,2	34,9	12,7	18,7
4	Surface soil sample No. 1044, 0-15	2,4	12,0	18,8	12,1	6,1	15,0	56,4	6,6	18,1	28,3	18,2	9,2
5	Same soil, 150-200	5,2	102,0	113,5	118,8	18,7	93,2	441,4	1,2	23,1	25,7	24,6	4,2
6	Ground water	4,4	229,2	716,1	55,0	412,5	482,1	1899,3	2,3	42,1	37,7	2,9	2,7
7	Drainage water No. 12, Dujaila Project	3,0	92,3	768,9	25,0	103,7	747,8	1740,7	0,2	5,3	44,2	1,4	5,9
8	Drainage water No. 14, same project	3,6	62,9	659,1	24,2	88,8	607,7	1446,3	0,2	4,3	45,5	1,7	6,0

Note: The analyses were kindly given the author by the Department of Development, Baghdad.

Note: Comma represents decimal point.

Table 2

Solubility of gypsum in the presence of other salts, in grams per liter

Salt	Salt concentration, %	Solubility of gypsum
CaCl ₂	3,50	1,549
"	6,94	1,345
"	10,36	1,121
NaCl	3,53	6,408
"	7,35	8,130
"	11,12	9,225

Note: Comma represents decimal point.

solonchaks of the sabach type, since irrigation waters are the same everywhere. This can be explained only by the properties of the soil, its water permeability, or the difference in the composition of exchangeable cations. Magnesium chloride can accumulate in large quantities only when it is leached from the soil layer where it forms, otherwise it will interfere with the decomposition of magnesium carbonate because of the action of the common ion. It was found (12) that salinization of the sabach type develops primarily in more permeable soils. The determination of the magnesium:sodium ratio in ground water would probably allow one to determine soils with good drainage, which is the main problem in the melioration of soils of this country.

In spite of the large quantities of calcium carbonate precipitating in the soils of Iraq, hardpans are not formed. This can be explained by the presence of gypsum in irrigation waters. Consequently, soil solutions contain a large amount of potassium ions, resulting in calcium carbonate precipitates in the form of small crystals, while the growth of large crystals is limited. A considerable amount of calcium carbonate contained in these soils is found in the clay and silt fractions.

Sodium carbonate salinization develops in the soils of Iraq, and causes high alkalinity. Their pH rarely exceeds 8. The cause for the absence of sodium carbonate in the soils is the presence of gypsum in the soil solution.



In conformity with this formula, the softening of gypsum waters occurs by the addition of sodium carbonate, which causes the precipitation of the least soluble salt—calcium carbonate.

Below we will try to explain the origin of sodium carbonate which is usually present in irrigated soils containing calcium carbonate and sodium chloride. Sodium carbonate is considered the final product of the process of salt transformations from calcium carbonate (7). This is unlikely because the latter salt itself is the final product because of its low solubility. To understand the process of formation of sodium carbonate, the following theories must be considered:

1. According to the Le Châtelier principle, the change of any factor in a solution having reached ionic equilibrium causes a reaction which balances the effect of this factor. Consequently, the sum of cations in a solution must always be equal to the sum of anions.

2. Sodium and calcium ions in a soil solution are of greatest interest. The relation between these ions is not constant; it varies as a result of cation exchange with soil particles when soil solutions become more diluted or concentrated (Donnan equilibrium). When dry soil is irrigated the soil solution becomes diluted, the Na-ion moves from the clay portion into the solution and is replaced by a calcium ion which is adsorbed by the clay from the soil solution. When the soil solution concentrates (as a result of evaporation or of the loss of water by transpiration) sodium is again replaced by calcium and passes from the solution into the adsorbed state.

3. When slightly soluble salt precipitates in the form of crystals and the ion composition favors its passage back into the solution (it contains soluble salt consisting of another anion and cation), the ions of the soluble salt can displace certain ions of the slightly soluble salt, and thus increase their quantity in the solution.

In soil solutions of saline soils, containing sodium chloride and calcium carbonate and lacking gypsum, the Ca-ion:Na-ion ratio changes when the soil is irrigated. When the soil solution is concentrated as a result of evaporation, the amount of Na-ions on clay particles increases, while the Ca-ions pass into solution. When the soil solutions are saturated with Ca-ions, they precipitate in the form of calcium carbonate. Carbonate ions become plentiful, since carbon dioxide in the soil solution loses its solvent. When the soil is irrigated anew, the soil solution becomes diluted and again the opposite process must take place. The calcium ions which are adsorbed once more by the clay particles become insufficient since they are fixed in the calcium carbonate crystals. Irrigation water adds new carbonate ions into the soil. Instead of calcium ions a somewhat larger amount of sodium ions dissociates from sodium chloride to balance the total anions, especially CO_3^{--} . The excess chloride ions from the sodium chloride combine with other easily available iron or aluminum cations, which are dissociated in a more alkaline solution. Iron and aluminum chlorides may be leached into deeper soil horizons and cause the formation of cracks of the columnar structure of soil. The foregoing process leads to the formation of somewhat more dissociated Na-ions in the soil solution; when the soil dries increased sodium pressure is partially exerted when the Na-ions are adsorbed by clay during the exchange process. With renewed irrigation, more sodium ions enter the soil solution, thereby displacing the process in the direction of formation of sodium carbonate. It is assumed that this displacement occurs more rapidly in soils with a higher exchange capacity.

The formation of sodium carbonate is impossible in the soils of Iraq, since the concentration of the Na-ion in the soil solution can increase only slightly as sodium chloride accumulates. This causes the high saturation of clay with sodium, but does not increase the pH of the soil

solution. Soils containing more than 15% of adsorbed sodium are called "alkali soils" (i.e., unfavorable for plant growth) in the United States. Their soil solution can be devoid of calcium ions which are necessary for the growth of plants because of the exchange adsorption of these ions by clay during irrigation. When the soils of Iraq are irrigated, additional calcium ions enter the soil at the expense of dissolved gypsum, so that the adsorption of 15% sodium does not destroy the plants. But when the content of exchangeable sodium is 30%-50% of the adsorption capacity, the soils become unproductive (1).

The application of additional gypsum under conditions of extensive agriculture in Iraq is not recommended (1). It is assumed that more frequent irrigation and larger amounts of percolated water would decrease the saturation of clay with sodium to an acceptable level, since the exchange capacity of the soils is low (18-22 meq) and, consequently, the amount of sodium ions is small.

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METHODS

NATURE OF HUMIC SUBSTANCES IN TRANS-URALS CHERNOZEMS

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A number of experimental investigations showed that the nature and properties of humic substances in various soils, and the qualitative state and composition of humus are closely related to their genetic characteristics, and depend on hydrothermal conditions and the nature of vegetation.

The nature of the humic substances in Trans-Urals chernozems, characterized by unusual, sharply-continental soil formation conditions are of great scientific and practical interest.

The new system of soil tillage, being developed by T. S. Mal'tsev, opens great possibilities for the proper use of local soil resources for increasing the effective fertility of soil.

This article discusses the results of a study of humus composition and certain properties of humic acids of chernozem-meadow, meadow-chernozem, and meadow-steppe soils from the "Zavety Lenina" kolkhoz in Shadrin district, Kurganskaya Oblast'.¹ The group and fractional humus composition in these soils to a depth of 40 cm, the content of water-soluble humus, and the ash composition of virgin meadow and meadow-steppe vegetation have been examined.

Characteristics of Soils Studied and Natural Conditions of their Development

Chernozem-meadow, meadow-chernozem, and meadow-steppe soils of the "Zavet Lenina" kolkhoz in the Shadrin district, Kurganskaya Oblast', are located on flat watershed plateaus and are primarily occupied by plowed fields among which there are small, virgin forest steppe areas. These three main groups of chernozem soils are widespread in the forest steppe belt of the Central Trans-Urals and are often called leached chernozem by analogy with soils in temperate climates. They differ from each other primarily by the depth of ground waters and water regime characteristics (1).

Thus the ground water is located at a depth

of 2 meters in chernozem-meadow soil and this soil has a leaching water regime of the semi-bog type and late thaw. The ground water in meadow-chernozem soils is found at a depth of 3-4 m. The water regime of these soils during the wet period is of the leaching type, while during the dry period it is of the periodic leaching, meadow-steppe subgroup.

Meadow-steppe chernozems differ from the above-mentioned two soils by deep ground water, below 6 meters. Morphologically these soils belong to leached chernozems and have a periodic leaching water regime.

All these soils freeze to a great depth (up to 1.5-2 m) under the severe climatic conditions of the Trans-Urals, thaw late (in mid-June), and have a cold thermal regime. In these respects they differ greatly from leached chernozems of the European USSR.

The common properties of these soils are their fine clay loam texture, and their high exchange capacity of 60 meq/100 g of soil (80 meq for meadow-chernozem soils), 50 meq which is due to exchangeable calcium.

The thickness of the humus horizon in all three subgroups varies from 40-65 cm. The humus horizon has a weakly acid reaction, the pH of the water extract from the upper 0-10 cm layer is 6.08-6.60. The humus content here is 8.43%-11.41%. The humus supply in the layer from 0-50 cm reaches 471 metric tons/ha, according to calculations of Afanas'yeva (1). These soils are biologically active. Their microflora is very diversified. It is represented by bacteria, actinomycetes, fungi, and cellulose-decomposing bacteria. It was established by the work of Mishustin and his coworkers (9) that the biogeneity of the soil increases when old plowed soils are tilled deeply under black fallow (according to Mal'tsev); bacteria, actinomycetes, and fungi develop better, especially in the layer from 0-20 cm; soil respiration intensifies so that more carbon dioxide is produced; and the process of nitrification becomes very active.

Such observations demonstrate the energy of the decomposition of easily mobilized organic substances in soil. Naturally, investigations in the course of one or two growing seasons cannot characterize the decomposition process of soil humus, since humic substances are decomposed

¹ From material collected by the brigade group of the Academy of Sciences of the USSR at "Zavety Lenina" kolkhoz. The scientific leader was academician I. V. Tyurin.

Table 1
Group and fractional composition of humus in chernozem-meadow soils

Profile No. and Soil	Depth, cm	Total C in % of the weight of initial soil	Humus C x 1.724	substances, benzene-alcohol extract	substances, sep. on decalcification	In the composition of humus							C.h. C.f.	Hydrolytically soluble in H ₂ SO ₄	Insoluble residue (humates)	Total	Total nitrogen	
						humic acids			fulvic acids								in % of soil	in the rest- air-dry soil
						Groups		Total	Groups		Total							
						1a	1		2	1a		1						
161	0-6	5.80 ^a	10.00	0.07 ^b	0.04	1.00	1.24	0.45	2.69	0.86	0.10	0.30	1.26	1.42	5.51	0.42	0.093	
Old plowed chernozem-meadow soil		$\frac{5.80}{100}$		$\frac{0.07}{1.21}$	$\frac{0.04}{0.09}$	$\frac{17.24}{17.24}$	$\frac{21.38}{21.38}$	$\frac{7.75}{7.75}$	$\frac{46.37}{46.37}$	$\frac{14.82}{14.82}$	$\frac{1.73}{1.73}$	$\frac{5.17}{5.17}$	$\frac{21.72}{21.72}$	$\frac{24.50}{24.50}$	$\frac{95.01}{95.01}$			
	26-36	2.24	8.86	0.05	0.02	0	0.92	0.21	1.13	0.23	0.17	0.14	0.54	0.52	2.34	0.16	0.043	
		$\frac{2.24}{100}$		$\frac{0.05}{2.23}$	$\frac{0.02}{0.88}$	$\frac{0}{41.07}$	$\frac{9.37}{9.37}$	$\frac{50.44}{50.44}$	$\frac{10.26}{10.26}$	$\frac{7.59}{7.59}$	$\frac{6.25}{6.25}$	$\frac{24.10}{24.10}$		$\frac{23.22}{23.22}$	$\frac{104.44}{104.44}$			
175	0-8	5.73	9.88	0.11	0.06	0.67	2.43	0.34	3.44	0.29	0.06	0.40	0.75	1.14	5.77	0.38	0.081	
Solonchetic chernozem-meadow soil abandoned for 25 years		$\frac{5.73}{100}$		$\frac{0.11}{2.00}$	$\frac{0.06}{1.04}$	$\frac{11.69}{11.69}$	$\frac{42.41}{42.41}$	$\frac{5.93}{5.93}$	$\frac{30.03}{30.03}$	$\frac{5.06}{5.06}$	$\frac{1.04}{1.04}$	$\frac{6.98}{6.98}$	$\frac{13.08}{13.08}$	$\frac{19.89}{19.89}$	$\frac{100.75}{100.75}$			
	25-35	4.42	7.62	0.06	0.04	0.52	2.08	0.30	2.90	0.24	0.01	0.15	0.40	0.79	4.42	0.31	0.034	
		$\frac{4.42}{100}$		$\frac{0.06}{1.35}$	$\frac{0.04}{0.90}$	$\frac{11.76}{11.76}$	$\frac{47.06}{47.06}$	$\frac{6.78}{6.78}$	$\frac{35.60}{35.60}$	$\frac{5.43}{5.43}$	$\frac{0.23}{0.23}$	$\frac{3.39}{3.39}$	$\frac{9.05}{9.05}$	$\frac{5.20}{5.20}$	$\frac{17.87}{17.87}$			
Solonchetic chernozem-meadow soil, disked for 4 years	0-7	6.62	11.41	—	0.26	0.97	2.48	—	3.45	—	0.66	—	0.66	1.80	6.17	0.55	0.17	
		$\frac{6.62}{100}$		—	$\frac{0.26}{3.93}$	$\frac{14.65}{14.65}$	$\frac{37.46}{37.46}$	—	$\frac{52.11}{52.11}$	—	$\frac{9.97}{9.97}$	—	$\frac{9.97}{9.97}$	—	$\frac{27.19}{27.19}$			
	7-14	6.63	11.43	—	0.37	0.93	2.59	—	3.52	—	0.60	—	0.60	1.76	6.25	0.47	0.16	
		$\frac{6.63}{100}$		—	$\frac{0.37}{5.58}$	$\frac{14.03}{14.03}$	$\frac{39.06}{39.06}$	—	$\frac{53.09}{53.09}$	—	$\frac{9.05}{9.05}$	—	$\frac{9.05}{9.05}$	—	$\frac{26.54}{26.54}$			
	14-21	6.15	10.59	—	0.59	0.78	2.36	—	3.14	—	0.54	—	0.54	1.43	5.61	0.48	0.14	
		$\frac{6.15}{100}$		—	$\frac{0.59}{8.13}$	$\frac{12.68}{12.68}$	$\frac{38.37}{38.37}$	—	$\frac{51.05}{51.05}$	—	$\frac{8.78}{8.78}$	—	$\frac{8.78}{8.78}$	—	$\frac{23.25}{23.25}$			

^aThe carbon content in individual groups of humic substances is given in the nominator in percent of the air-dry initial soil; the same is given in the denominator, but in percent of organic soil carbon.

^bC h. — C in humic acids; C f. — C in fulvic acids.

Profiles 161 and 175 were analyzed by P. N. Vysotskaya.

Note: Comma represents decimal point.

Table 2
Group and fractional composition of humus in meadow-chernozem and meadow-steppe soils

Profile No. and soil	Land use	Depth, cm	Total C in % of soil weight	Humus C x 1.724	Substances extracted from benzene-alcohol extract	Substances extracted from decalcification	Humic acids			Fulvic acids			C h. Cf.	Insoluble residue (humates)	Total	Total N in % of air-dry soil	
							Groups		Total	Groups		Total					
							1a	1		2	1a						1
307 Solonchik meadow-chernozem	Wheat after fallow	0-5	4.89 100	8.43	—	0.28 5.73	0.52 10.63	1.89 38.15	—	2.41 49.28	0.30 6.17	0.27 5.49	—	4.22 11.66	1.23 25.15	4.49 91.82	0.41
		20-30	3.98 100	6.85	—	0.30 7.54	0.25 6.28	1.72 43.21	—	1.97 49.49	0.30 7.54	0.22 5.52	—	3.79 13.06	1.04 23.13	3.83 93.22	0.31
292 Meadow-steppe	Virgin	5-10	5.02 100	8.65	—	0.30 5.98	0.63 12.55	1.56 31.07	—	2.19 43.62	0.38 7.57	0.38 7.57	—	2.92 15.14	1.43 28.48	4.68 93.22	0.36
		20-30	2.81 100	4.86	—	0.08 2.85	0.07 2.49	1.12 39.85	—	1.19 42.34	0.19 6.76	0.28 9.96	—	2.53 16.72	0.86 30.10	2.60 92.51	0.24
Meadow-chernozem soil from Kamennaya Step. meadow Voronezh oblast'	Abandoned land;	0-7 ^a	7.35 100	12.69	3.7	4.1	30.3	6.0	36.3	19.6	2.8	22.4	1.6	31.2	97.7	—	
Ordinary chernozem	1 year grass	0-20 ^a	4.79 100	8.27	4.0	2.2	31.3	9.2	40.5	16.7	2.9	19.6	2.1	32.5	99.8	—	
Strongly humic, slightly solonchik chernozem, North Kazakh.		0-10 ^b	6.34 100	10.93	3.0	1.3	—	—	41.1	—	—	14.0	2.9	33.8	93.2	—	

^aFrom the work of N. P. Bel'chikova.

^bFrom the work of A. M. Durasov.

Note: Comma represents decimal point.

HUMIC SUBSTANCES

lowly under conditions of a cold thermal soil regime. In the Trans-Urals this process is complicated by sharply continental climatic factors, specific for the area, which change greatly with the seasons. The long winter with low air and soil temperatures (7-8 months) is replaced by a short, hot summer. After the soil has frozen deeply and thawed late, frequent frosts follow in April or June. The deep wetting of the soil by atmospheric precipitation in autumn or melt water in spring does not compensate for the moisture deficit in soil in summer.

These natural factors periodically dampen microbiological activity for a long time and activate it during the short, hot summer. Such conditions usually insure the concentration of humic substances, and promote the formation of organo-mineral compounds and the accumulation of much humus in the soil.

We took the following soils to study humus:

1. Old plowed chernozem-meadow soil. Krivskaya area, Profile 161. The ground-water level in the spring of 1954 was at 2.2 m (as determined by P. U. Bakhtin). Effervesces from HCl at a depth of 66 cm.

2. Plowed chernozem-meadow soil which had been disked in the last 4 years. Krivskaya area, at a distance of 300 m from Profile 161. The soil is solonchic. In 1950 it was under deep fallow (according to Mal'tsev), the following 3 years wheat was sown, and in 1955 vetch with oats were sown over the disked soil.

3. Chernozem-meadow soil, abandoned for 5 years. Stud farm area, Profile 175. The soil is solonchic. The ground-water level is at 1.8-2.8 m.

4. Plowed meadow-chernozem soil. Stud farm area, Profile 307. Spring wheat over fallow. The ground-water level is at 3-4 m. Effervesces from HCl at a depth of 105 cm.

5. Virgin meadow-steppe soil. Pasture between the villages of Ganino and Ivanishchevo. Profile 292. Mixed grass (sheep's fescue) vegetation. Ground water at a depth of 6 m. Effervesces from HCl at a depth of 80 cm.

Content and Composition of Humus in the Soils Studied

The Tyurin method (11)² was used in the determination of the total content and composition of soil humus.

Table 1 gives group and fractional composition of humus in chernozem-meadow soils. These data show that the humus content in the upper 0-8 cm layer is high, reaching 10%-11.4%; the amount of humic acids in the composition of humus in the virgin area is 60%-65% of total organic carbon, and in the old plowed area, 46%-50%. Up to 40%-47% of humic acids are bound with calcium (group I).

The ratio between the C of humic acids and the C of fulvic acids is considerably higher than one (2.1). In solonchic soils this ratio reaches 5.8 and even 7.1.

The amount of free humic acids or humic acids bound with the mobile forms of R_2O_3 is considerably relative to the total content of humic acids; it is 18%-28%, and even 38% in the upper horizon of old plowed soil (Profile 161). Attention is drawn to the relatively small non-hydrolyzing residue of humic substances.

Data on humus content and composition in meadow-chernozem and meadow-steppe soils are given in Table 2. These soils are also characterized by the predominance of humic acids, which is strongly bound with calcium 30%-

²Working method adopted by the Laboratory for the Biochemistry and Biology of Soils at the V. V. Dokuchaev Soil Institute, Academy of Sciences, USSR.

Table 3

Ash composition of meadow and meadow-steppe with virgin vegetation. Central Trans-Urals, 1956

Vegetation ^a	Parts of plant, cm	Total N, %	Pure ash, %	In % of pure, non-carbonate ash					
				SiO ₂	P ₂ O ₅	CaO	MgO	K ₂ O	Na ₂ O
Meadow	Tops	2,87	8,07	27,08	6,84	17,16	6,66	30,67	2,69
	Roots								
	0-40	1,74	5,15	22,79	7,28	19,87	14,92	18,59	3,15
	40-80	1,38	5,80	15,09	8,62	15,26	8,44	21,50	13,02
Meadow-steppe	Tops	1,62	7,90	51,47	6,00	8,09	3,71	17,96	0,96
	Roots								
	0-40	1,05	6,56	55,67	3,20	14,00	5,15	6,84	1,82
	40-80	1,46	6,67	28,06	3,69	18,58	7,76	11,70	5,57

^aPlant samples were taken on August 9 and 12.

Note: Comma represents decimal point.

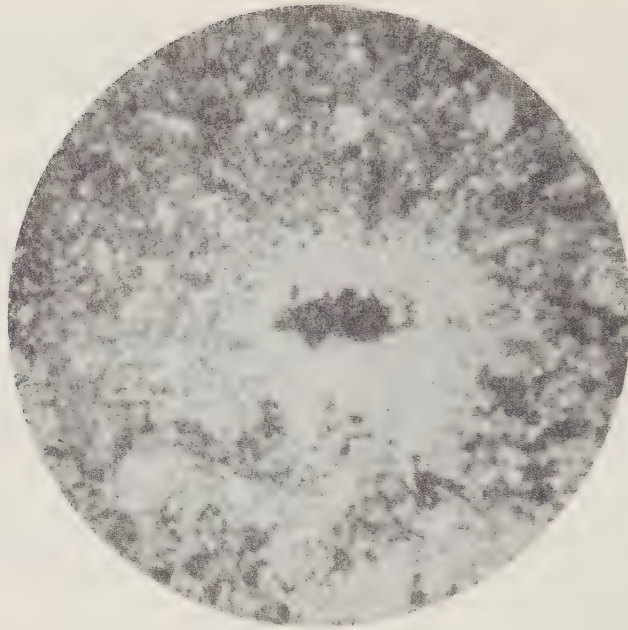


Fig. 1. - Calcium carbonate around a pore; crossed nichols, magnified 80 times.

43% of total organic carbon) in humus. There are noticeably less mobile humic acids in these soils, especially at a depth of 20-30 cm. They amount only to 2.49% of total carbon, or 5% of the total amount of humic acids, in virgin meadow-steppe soil. As in the first case (chernozem-meadow soils) attention is drawn by the small amount of substances separated during the decalcification of soil (from 0.08%-0.30%). This illustrates the considerable humus stability in the foregoing soils.

Here attention must be paid to a very important fact: the grass meadow vegetation, which participates in the formation of these soils, accumulates in its roots and shoot a large amount of cations, calcium in particular (up to 20%), with which it enriches the upper humic soils layers (Table 3).

Grass meadow-steppe vegetation contains less calcium in its tops, since silica predominates in the steppe components (e.g., in sheep's fescue). However, there is a large amount of calcium in their roots, reaching up to 18% of the weight of pure ash.

We noted the concentration of calcium in the root of perennial meadow grasses when studying the ash composition of timothy (3). We must also note the rise of calcium from the lower-lying horizons during the capillary rise of water which may be seen when thin sections of undisturbed soil are studied under a polarizing microscope. The picture clearly shows the large amount of carbonates which are scattered around a pore at a depth of 110 cm in meadow-chernozem soil (Profile 101).

The qualitative humus composition in cherno-

zem-meadow, meadow-chernozem, and meadow-steppe soils is similar in many respects to strongly humic, slightly solonetzic chernozems of Northern Kazakhstan (5) and chernozems in the European USSR (2, 6, 7). A comparison of humus group composition in chernozem at three geographical points shows that the Trans-Urals chernozems are distinguished by a higher content of humic acids in the composition of humus. In conformity with this the ratio between the C of humic acids and the C of fulvic acids is wider in these soils. As shown in our studies, it is especially wide in the solonetzic varieties.

The amount of fulvic acids in solonetzic chernozem-meadow and meadow-chernozem soils is small compared with that of humic acids. It is 9%-13% of the total organic carbon in the soil (Tables 1 and 2). An assumption had been voiced, based on the general nature of humification under given natural conditions, that newly forming fulvic acids (as a result of the decomposition of a large amount of organic remains in spring with excessive moisture) may partially change into humic acids during the dry summer period, and become fixed in the soil in the form of calcium humates in the presence of calcium.

In addition, one may have assumed that fulvic acids are very mobile here because of their solubility in water, especially when the soil is solonetzic. However, determinations of the content of water-soluble humus in chernozem-meadow soils did not confirm this (Table 4).

The reaction of these soils was weakly acid, even though a number of data indicated that they were obviously solonetzic. These were primarily morphological indices of the soil profile, such as the presence of a very compact horizon at a depth

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Table 4
Amount of water-soluble humus and pH

Profile No. and soil	Depth, cm	pH in water	Water-soluble organic substance in % of air-dry soil
161 Old plowed chernozem-meadow	0—8 26—36	6,36 6,44	0,05 0,03
Solonetzc chernozem-meadow, abandoned for 25 years	0—8. 25—35	6,08 6,06	0,06 0,05
Solonetzc chernozem-meadow, disked for 4 years	0—7 7—14 14—21	6,60 6,30 6,04	0,04 0,06 0,06
307 Plowed meadow-chernozem	0—5 20—30	6,25 6,34	Not det'd. "
292 Virgin meadow-steppe	5—10 20—30	6,10 6,40	" "

Note: Comma represents decimal point.

Table 5

Ratio between C of humic acids and C of fulvic acids after treatment with 0.1-N NaOH, without the prior decalcification of soil

Soil	Depth, cm	Treatment with 0.1-N NaOH					
		without decalcification			after decalcification with 0.05-N H ₂ SO ₄		
		C h.	C f.	$\frac{C h.}{C f.}$	C h.	C f.	$\frac{C h.}{C f.}$
Solonetzc chernozem-meadow, disked for 4 years	0—7	1,31	1,10	1,19	1,27	0,22	5,77
Solonetzc chernozem-meadow, abandoned for 25 years, Profile 175	0—8	1,18	0,98	1,20	1,05	0,22	4,77

Note: Comma represents decimal point.

of 15-20 cm, structureless, and sticky when wetted (when washing the soil monoliths with plants). There were 2.6 meq of sodium in the composition of adsorbed cations; an obvious concentration of sodium (13% of the weight of ash) was found in the roots of virgin vegetation (Table 3).

It is quite obvious that the solonetzc varieties of the soils studies are characterized by other forms of humic substances and by a different bond between them and the mineral part

of the soil than chernozems which are not solonetzc.

In examining the types of bonding (or states) of humic acids in various soils in 1949, Tyurin (12) noted that the polymeric complexes of fulvic acids with humic acids (forming much the same as complex esters), become hydrolyzed under the effect of weak alkaline solutions if the acid groups of these complexes are not protected by exchangeable calcium, but are free, or bound with sodium (as in solonetzes).

The nature of humic substances, separated by weak alkali before and after decalcification, was studied later by Kononova and her coworkers (6) and recently by Khan (14). In relation to this we made the following experiment.

Small samples (of 1 g) of solonetzic soils were treated with 0.1-N NaOH without being previously decalcified, until humic acids were fully separated. The remainder of the soil was subjected to decalcification with 0.5-N H_2SO_4 , after which it was again treated with 0.1-N NaOH. The carbon in humic and fulvic acids was determined in both cases (Table 5).

It was proven that almost half of the humic substances extracted from the soil which was not decalcified prior to treatment with 0.1-N NaOH, consisted of fulvic acids. After the soil had been decalcified with 0.05-N H_2SO_4 , humic acids were released, which were primarily bound with calcium; 5 times less fulvic acids were released.

The results obtained are in agreement with the investigations of Khan, who, using 0.1-N alkali to fractionate humic substances without decalcification and after decalcification, experimentally established definite differences between the chemical composition of humic acids of various soils in the $<1 \mu$ diameter fraction. Khan believes that the group of humic substances in soil which is extracted with 0.1-N NaOH without being decalcified is primarily associated with calcium, aluminum, and iron which are adsorbed at the surface of clay minerals of the montmorillonite group. Since calcium is partially replaced by sodium in the solonetzic varieties, it is possible that a certain amount of fulvic acids being the most mobile part of the polymetric complexes of humic substances, is removed under conditions of an intermittent water regime of the leaching type. This removal could have taken place after the rise of sodium into the upper soil horizons previous to our investigations.

Conclusions

1. Chernozem-meadow, meadow-chernozem, and meadow-steppe soil, which are widespread in the forest steppe zone of the Central Trans-Urals, are characterized by a high humus content and are very productive.

2. Humic acids predominate in the humus composition of these soils, being 60%-65% of the total organic carbon in chernozem-meadow soils, 49% in meadow-chernozem soils, and 43% in meadow-steppe soils. Up to 40%-47% of the humic acids are bound to calcium. The humus of the foregoing soils is not very mobile, which is evidenced by the small amount of organic substances extracted during decalcification (0.08%-0.30% of total carbon).

3. The ratio between the C in humic acids and the C in fulvic acid is 2.1-2.9 and is typical for chernozem soils.

The ratio between the C in humic acids and the C in fulvic acids is wide in solonetzic vari-

eties (4.2, 5.8, 7.1).

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PROPERTIES OF SOILS IN THE KLYAZ'MA RIVER FLOOD PLAIN AND THE MINERALOGICAL COMPOSITION OF THEIR CLAY FRACTION

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Soils of river flood plains are of great interest, even though they occupy a comparatively small area. They fill a practical need when used for growing vegetables and valuable forage crops. The best meadows and pastures are located in the flood plains of rivers of the northern belt and they can be used properly only after their soil properties have been studied.

Soil-formation conditions in flood plains are very unusual. B. B. Polynov (13) notes these characteristics: 1) unusual soil-forming parent

materials which are recent alluvial deposits; 2) radical periodic changes of hydrogeological conditions of soil formation associated with floods; and 3) the progressive change in soil-formation conditions associated with the directed activity of an entire river system or one of its parts. Buried soils are often found in flood plains, which apparently had formed under different hydrological regime conditions.

Judging by the foregoing characteristics, the improvement of these soils requires specific

Table 1

Particle-size analyses of soils of the Klyaz'ma River flood plain (% of air-dry sample)

Area Number and soil	Depth, cm	Particle diameter, mm						
		1—0,25	0,25—0,10	0,10—0,01	0,01—0,005	0,005—0,001	<0,001	<0,01
1. Sod	0—4	2,50	16,73	52,86	2,69	6,19	19,03	27,81
	14—24	0,25	30,70	49,48	1,60	3,40	14,57	19,57
	100—110	0,68	39,62	49,70	0,67	1,82	7,51	10,00
2. Sod-meadow	0—7	25,84	5,39	20,29	5,50	16,86	26,41	48,48
	7—15	18,90	9,89	21,68	6,27	14,72	28,54	49,53
	18—28	16,64	10,57	27,53	4,55	10,82	29,89	45,26
	40—50	7,79	12,11	38,33	5,88	10,20	25,69	41,77
	90—100	1,72	4,54	35,36	6,66	9,52	42,20	58,38
3. Ferruginous meadow-bog	0—6	32,65	7,21	30,65	4,77	10,30	14,42	29,49
	23—33	24,61	18,58	27,28	3,98	7,60	17,90	29,48
	50—60	12,23	17,51	29,01	4,78	6,04	30,43	41,25
	110—120	67,36	28,36	2,30	—	0,25	1,73	1,98
4. Peat-gley	10—20	10,55	16,05	36,64	4,46	11,82	20,48	36,76
	44—49	19,41	8,95	20,78	6,42	13,66	29,78	50,86
	70—80	2,54	16,68	36,97	4,69	10,56	28,56	43,81
	105—115	16,88	12,88	22,61	6,66	13,37	27,60	47,63
5. Slightly podzolic sod	3—13	43,10	36,62	13,23	1,65	3,15	2,25	7,05
	35—45	39,15	36,56	18,80	1,61	2,47	1,41	5,49
	160—170	19,83	27,95	28,18	2,56	4,56	16,92	24,04

Note: Comma represents decimal point.

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Table 2
pH of the soils investigated

Area number and soil	Horizon	Depth, cm	pH	
			water	salt
1. Sod	A _s	0—4	6,26	5,11
	A ₁	4—13	6,26	5,11
	B ₂	27—37	6,26	5,11
	C	100—110	6,26	5,01
2. Moderately sod-meadow	A _s	0—7	5,29	4,25
	A ₁	7—15	5,20	4,20
	A _{buried}	18—28	5,20	4,20
	B	40—50	5,33	4,15
	B _g	90—100	5,29	4,05
	C	120—130	5,67	4,52
3. Ferruginous meadow-bog	A _s	0—6	6,02	4,76
	A ₁	6—16	5,38	4,66
	B	23—33	5,38	4,37
	B _g	50—60	6,04	4,37
	C ₁	110—120	6,04	4,37
	C ₂	167—176	6,04	4,66
4. Peat-gley	A ₁	10—20	5,29	4,37
	g	44—49	5,29	4,56
	B _g	70—80	5,29	4,48
	C _g	105—115	5,29	4,37
5. Slightly podzolic sod	A ₀	0—3	4,93	4,24
	A ₁	3—13	5,04	4,37
	A ₁	20—30	5,08	4,40
	A _{2g}	35—45	5,08	4,17
	B ₁	85—95	5,08	4,37
	C	160—170	5,08	4,37

Note: Comma represents decimal point.

gricultural measures.

A number of works have been been published on the problem of the reclamation of flood plain lands (1, 17, 9, 10, 6, 15, 16, 12). The regional works of Lyutin, Borovski, and Kovrigina (11, 18) recommend measures based on the study of soil, while the work of Shrag (17) gives a general account of the work done in the reclamation of flood plain lands and the characteristics of soils in various types of flood plains.

We studied the soil of the Klyaz'ma River flood plain at the boundary between the Kirovsk region, Vladimir Oblast', and Savinov rayon, Ivanov Oblast', north of Knyaginkino village.¹

The soils of the Klyaz'ma River flood plain develop primarily under rich herbaceous vegetation. Soil-formation conditions differ in various parts of the flood plain. Grass - mixed herb associations predominate along the river, hair grass - foxtail predominate in the central part of the flood plain, hair grass - mixed herb vegetation predominates in drier areas on the terrace side, and sedge vegetation in the more moist part. Vegetation is especially luxuriant in the central part of the flood plain, where good soil structure is present. The relief changes from the along river to the terrace side from ridge-gulchy to more leveled.

The proximity of ground water to the surface has a great effect on soil formation. Ground water was found at a depth of 3.5 m along river of the flood plain, at 1.5 m in its central part, at 1.2 m on the drier part of the terrace side, and almost at the surface in its wetter part. Vegetation is more moisture-loving in the depressed areas of the flood plain, where the ground

¹Our work was part of the investigations conducted by the Soil Science Chair of Moscow State University in this part of the flood plain under the leadership of G. B. Dobrovol'skiy and N. G. Zyrin.

Table 3

Chemical characteristics of soils from the experimental area (mg/100 g of absolutely dry soil)

Area number and soil	Horizon	Depth, cm	Hydrolyzable N		P ₂ O ₅ in 0.5% CH ₃ COOH		Exchangeable potassium	
			first	second	first	second	first	second
1. Sod	A _S	0-4	9,84	10,87	8,40	6,25	2,11	2,44
	A ₁	4-14	10,83	9,84	3,59	4,30	1,62	1,61
	B ₁	14-24	9,35	8,29	2,95	3,06	1,92	0,64
2. Moderately sod-meadow	A _S	0-7	21,92	21,41	3,25	2,94	7,56	8,85
	A ₁	7-17	18,11	17,59	1,81	1,53	2,26	2,43
	A _{buried}	18-28	11,67	11,81	1,90	2,54	2,49	0,51
3. Ferruginous meadow-bog	A _S	0-6	26,75	27,26	3,18	3,04	10,96	3,44
	A ₁	6-18	15,05	13,44	4,89	2,67	3,66	11,01
	B ₁	20-30	12,31	13,21	2,93	5,17	0,33	0,32
4. Peat-gley	A ₀	0-10	23,01	Not det.	3,62	8,04	5,62	4,90
	A ₁	10-20	21,68	22,74	2,68	2,03	1,72	0,57
5. Slightly podzolic sod	A ₀	1-3	11,98	11,59	0,87	1,74	9,21	0,47
	A ₁	3-17	9,08	7,20	3,43	1,71	1,86	10,84
	A ₁	20-30	5,55	8,10	2,86	1,37	0,62	4,34

Note: Comma represents decimal point.

water is near the surface and the soil is touched by gleization.

To characterize the soils of the flood plain most fully, considering the diversity of soil-formation conditions, four areas were selected in various parts of the flood plain: 1) along the river with coarse clay loam sod soil on stratified alluvium; 2) in the central part of the flood plain with moderately soddy soil on buried meadow soil; 3) in the drier area on the terrace-side with ferruginous meadow-bog soil on sandy alluvium; and 4) in the moister area on the terrace-side with peat-gley soil. The fifth area was located on the watershed on the other bank of the Klyaz'ma River with slightly podzolic sod soil.

The soils differ in texture in various parts of the flood plain (Table 1). There are also differences within one and the same soil profile, which indicates the diversity of the river alluvium. The soil in area 1 texturally belongs to coarse clay loam, according to the classification of Kachinskiy (7), that in area 2, to fine clay loam, since it contains more than 41%-45% of <0.01 mm diameter particles and more than 25% of the clay fraction. The content of >0.25 mm diameter particles varies from 25%-1.7%. The texture of the soil in area 3 is heterogeneous along its profile. The content of <0.01 mm diameter particles in the upper horizon is 29.4%, it increases to 41.2% at a depth of 50-60 cm, and drops to 1.98% at a depth of 110-120 cm. Texturally the most homogeneous soil was found in area 4,

where the content of <0.01 mm diameter particles varies from 40%-50%. Soil in area 5 (watershed) was found to be of coarser-texture to a depth of 67 cm (the 35-40 cm layer was analyzed), and became finer below, which points to the two-layered soil-forming parent material.

The availability of many chemical elements, determining the nutrition of plants, is associated with the active reaction of the medium. The soils of the Klyaz'ma River flood plain are generally weakly acidic (Table 2). The pH of the water suspension varies from 6.25-5.20, whereby area 1 is distinguished by a more alkaline reaction of the medium. The pH does not vary within the soil profile. The pH drops to 4.93-5.08 in the soil of the watershed. The pH of the salt suspension of the soils studied varies from 4.05-5.11, whereby there are no significant variations in the pH from horizon to horizon.

To assess the amount of nutrients in the soils of the flood plain, we determined nitrogen, phosphorus, and potassium on a duplicate sample obtained by mixing soil taken at five points of an area (4 on the corners and 1 in the center). The rich herbaceous vegetation of the flood plain draws a large amount of substances into the biological cycle, enriching the upper soil layers with mineral nutrients. The flood plain regime leaves a definite impression on the mineralization of organic remains. The favorable alternation of wetting and drying results in the accumulation of humus in flood-plain soils. Temporary floods may remove the most soluble compounds from the

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Table 4

Total chemical composition of the <0.001 mm diameter fraction from soil of the Klyaz'ma River flood plain (% of ignited sample)

Area number and soil	Depth, cm	Hygroscopic moisture	Ignition loss	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	P ₂ O ₅	CaO	MgO	SiO ₂ / K ₂ O ₃
1. Sod	0—4	6.49	20.47	53.08	23.63	16.85	0.19	0.81	2.54	2.61
	14—24	6.80	15.28	51.87	23.92	17.87	0.21	0.76	2.67	2.48
	100—110	7.01	12.26	55.76	20.97	14.68	0.05	0.73	2.50	2.93
2. Sod-meadow	0—7	6.19	23.66	57.80	21.08	14.45	0.74	0.75	3.65	3.29
	7—15	7.17	17.49	57.07	24.35	13.97	—	0.78	2.39	2.80
	18—28	8.95	13.49	54.91	24.27	14.45	—	0.60	2.29	2.78
	40—50	8.77	12.34	55.37	25.98	13.45	—	0.56	2.05	2.71
	90—100	8.11	9.48	55.94	24.53	14.73	—	0.79	2.52	2.97
3. Ferruginous meadow-bog	0—6	5.93	25.95	53.85	26.51	13.26	0.41	0.87	1.88	2.70
	23—33	7.33	14.72	56.04	24.80	13.52	0.6	0.87	2.54	2.84
	50—60	8.11	9.83	52.39	25.18	17.62	0.06	0.71	2.35	2.47
	110—120	6.73	11.84	54.07	29.49	10.87	0.14	0.78	2.68	2.51
4. Peat-gley	10—20	6.78	27.29	57.66	26.87	10.01	0.01	0.98	2.32	2.94
	44—49	6.34	23.74	59.81	26.30	10.60	0.41	0.50	2.63	3.02
	70—80	8.49	10.43	51.95	32.82	11.87	0.14	0.66	1.37	2.91
	105—115	7.07	14.97	56.36	19.24	19.18	0.82	0.75	1.61	2.96
5. Slightly podzolic sod	3—13	4.59	20.12	54.90	27.04	11.36	0.41	0.53	2.76	2.72
	35—45	3.01	12.14	54.92	27.03	11.29	0.39	0.82	2.55	2.71
	160—170	6.14	9.66	53.18	26.58	14.17	0.17	0.40	2.47	2.53

Note: Comma represents decimal point.

plant residues, in particular potassium. The enrichment of soils with mobile iron undoubtedly affects the combination of phosphorus into forms only slightly available to plants. The Fe⁺⁺⁺ in a 1-N solution of H₂SO₄ reaches 50 mg, while Fe⁺⁺ reaches 40 mg per 100 g of absolutely dry soil in the upper horizon and sharply increases (up to 1300 mg) in the lower horizon of area 4.

We determined the hydrolyzable forms of nitrogen in a 0.5-N extract of sulfuric acid in mixed samples by the Tyurin method in July and again in September. The results of the analysis (Table 3) indicate that the flood plain soils are rich in easily decomposing, hydrolyzable forms of nitrogen. The highest amount of nitrogen is contained in the soils of areas 2, 3, and 4 (27–23 mg/100 g of absolutely dry soil), where herbaceous vegetation is luxuriant. The content of hydrolyzable nitrogen decreases with depth. Slightly less nitrogen was found in soils along the river and on the watershed, amounting to 9–10 mg per 100 g of absolutely dry soil. This is associated with the change in the type of vegetation and different conditions of the decomposition of organic residues. The nitrogen content does not change in soil along the river to a depth of 24 cm, while it decreases within the depth limits investigated by us in the soil of the watershed. Observations on the hydrolyzable nitrogen content in July and September showed

that no significant changes occurred during this period in any of the soils. It is mentioned in the work of Korableva and Prokhorova (10) that 8–4 mg of hydrolyzable nitrogen in 100 g of soil are entirely sufficient for potato and beet. The data of Prokhorova (14) on the dynamics of nutrients in the flood plain of the Moskva River also confirm the weak effect of nitrogen fertilizers. The soils of the Klyaz'ma River flood plain, which are considerably richer in hydrolyzable forms of nitrogen, apparently do not require organic fertilizers.

Phosphates were determined in a 0.5-N extract of acetic acid by the F. V. Chirikov method. The following groups of phosphates enter this extract: Ca₃(PO₄)₂, part of CaX₂Ca₃(PO₄)₂, part of AlPO₄ and the salts of alcohol- and saccharo-phosphoric acids. Chirikov and Volkova (19) established that forms of phosphorus soluble in acetate are taken up by plants differently, depending on the properties of the soil and plants. This form of phosphorus is generally assimilated, this is why its content in the soil indicates to what degree soil is supplied by available P₂O₅. Data on the content of P₂O₅ in a 0.5-N extract of acetic acid (Table 3) show that there is little available phosphorus in the soils of the flood plain and of the watershed (2–4 mg/100 g of absolutely dry soil). Somewhat more phosphorus was found in the soils of area 1 (8.4–6.25 mg in the upper A₃

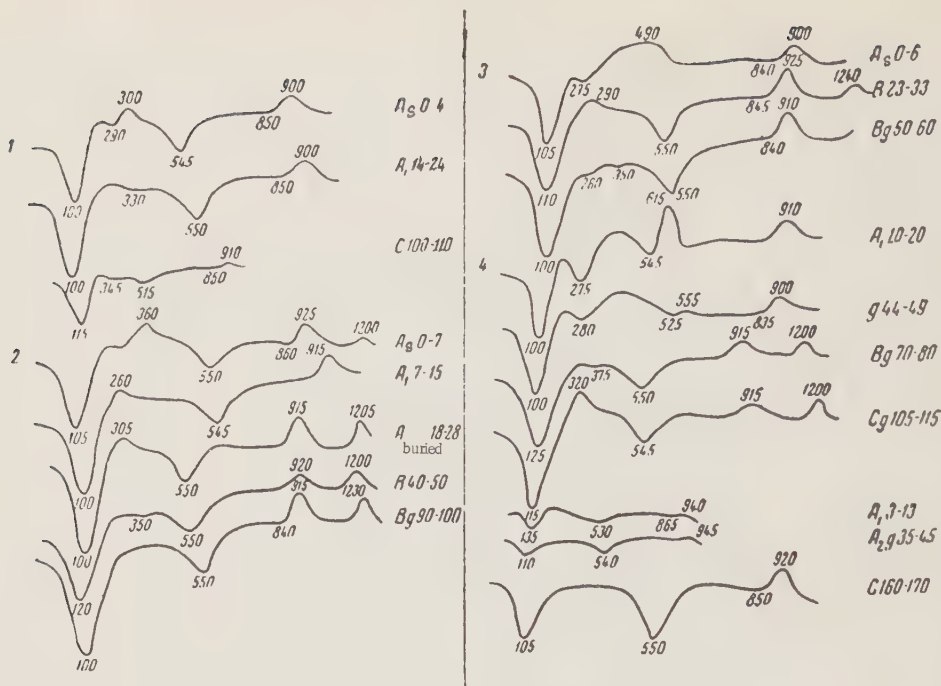


Fig. 1. - Thermograms of the 0.001 mm diameter fraction from the soils of the Klyaz'ma River flood plain and the watershed.

Area numbers, 1-5. Soil: 1 - sod; 2 - moderately sod meadow; 3 - ferruginous meadow-bog; 4 - peat-gley; 5 - slightly podzolic sod. The depth of the horizons is given in centimeters.

horizon). Apparently phosphorus is bound to iron and aluminum hydroxides, the total content in the <0.001 mm diameter fraction is about 40% (Table 4). Askinazi (2) found that the phosphates of sesquioxides are poorly soluble in an acid medium, but when it is alkalinized the passage of P_2O_5 into solution increases. Proceeding from the foregoing, one may conclude that the soils of the Klyaz'ma River flood plain require phosphorous fertilizers. Chirikova and Aleksandrovskaya (18) proved that when superphosphates are applied, most of the phosphates remain in available forms in moderately podzolized soils.

Exchangeable potassium was determined in the same mixed samples by the method of V. G. Aleksandrova. As shown by the experiments of Gorbunov and others (5), exchangeable potassium is easily taken up by plants. It follows from the data given in Table 3 that the soils of the Klyaz'ma River flood plain are poor in available potassium. Its content decreased regularly with depth (within 30 cm) in all the flood plain soils during the first period of observation. The content of exchangeable potassium varied from 7-10 mg/100 g of absolutely dry soil in the sod horizon of soils in areas 2 and 3 and in the litter of area 5, while it dropped to 2 mg in the soil of area 1. During the second period of observation, the total content of potassium to a depth of 30 cm hardly changed. A certain change was observed in the distribution of exchangeable potassium from horizon to horizon in the soils of areas 5 and 3, while in the rest of the soils the distribution was the same as during the first period of

observation. The change from horizon to horizon may be associated with leaching of potassium and its transition to a non-exchangeable state as the soil dries out (4, 14).

The most active part of the soil is the <0.001 mm diameter fraction. Clay minerals are concentrated in it, the determination of which may be used to predict many of the physicochemical properties of the soil. We determined the mineralogical composition of clays by thermal and X-ray analyses (5). The thermograms are shown in Figure 1. The nature of the curves is similar to that of the predominating clay minerals and only admixtures introduce certain peculiarities. The thermograms show three endothermal effects: at 100°C, 550°C, and in certain cases at 840°-860°C. All thermograms exhibit exothermal effects with a maximum at 900°-920°C and an effect at 1200°C on almost all thermograms. Such curves are characteristic for minerals of the montmorillonite group. The considerable magnitude of the endothermal effect indicates the presence of an admixture of hydrophilic substances. Certain thermograms exhibit an exothermal effect at a temperature of about 300°C. This effect may be produced by the combustion of organic substances that are not easily oxidized, and by the oxidation of ferrous compounds. The largest amount of such substances was found in the soils of areas 1 and 2 (peaty-gleyey to a depth of 49 cm and meadow-bog at a depth of 0-6 cm). This effect does not appear in the soil of area 5 (watershed), even on the thermogram of the clay fraction from the upper horizon.

The thermograms of the <0.001 mm diameter fraction from flood plain soils exhibit an endothermal effect at temperatures from 275°-350°C, which points to the presence of sesquioxide minerals: goethite— Fe_2O_3 giving an effect at 340°C, and hydrargillite $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, at 275°C. When they are present together, it is almost impossible to separate them, the more so because there are peaks on our thermographs in the same temperature range, which are caused by the oxidation of organic substances. The largest amount of sesquioxide minerals was found in the soils of area 4, whereby hydrargillite predominated in the A_1 and G horizons, while the presence of goethite became relatively more noticeable in the lower horizons. Pyrite (exothermal effect at 615°C) was found in the A_1 horizon of the same soil, which points to intense gley formation. A somewhat lesser amount of sesquioxide minerals was found in the soils of areas 1, 2, and 3. These minerals were not found in the soil of area 5; there were less amorphous hydrophilic substances here. The increase of the endothermal effect at 550°C in the <0.001 mm diameter fraction of the soil on the watershed is possibly associated with admixtures of kaolinite.

Data of the X-ray analysis indicate the presence of a mineral of the montmorillonite group and an admixture of hydromica. This is evidenced by reflections in the region 15-10 kX; 35 kX; 2.5 kX; 1.99 kX; 1.66 kX; and 1.54 kX. Apparently there are mixed-layer minerals in the soils studied, since a diffuse halo is observed in the region of small angles. In the X-ray photographs of the <0.001 mm diameter fraction from the soil of the flood plain there is an appreciable amount of background darkening, which points to the presence of hydrophilic and amorphous colloids (allophanes, and organic substances). Certain peculiarities are found on the X-ray photographs of the <0.001 mm diameter fraction from the soils of the watershed. The presence of a small amount of kaolinite was found together with hydromica and the mineral of the montmorillonite group at depths of 3-13 cm (A_1 horizon) and 35-43 cm (A_g horizon). This is evidenced by basal reflections 7.15 kX and 3.52-3.58 kX. This is especially clear in the A_g horizon, whereby the crystallization of clay minerals in this and the overlying horizons is better than at a depth of 160-170 cm, where the parent material is located. Clay minerals are much more poorly crystallized in the soils of the flood plain. The transport of clays by rivers and their redistribution have apparently destroyed part of the crystals of secondary minerals.

Various minerals form under various conditions of soil formation. Under the special conditions of the moisture regime of flood-plain soils, sesquioxide minerals form (goethite and hydrargillite). Flood-plain soils are richer in hydrophilic, amorphous substances, such as allophanoids and organic compounds, than those of the watershed.

Data on the total chemical composition of the <0.001 mm diameter fraction, extracted from the soils of the flood plain and of the watershed (Table 4) show that the clay minerals are enriched in magnesium and are comparatively poor in calcium (<1%). The MgO content in all samples varies about 2%-2.5%, except for the A_1 horizon of the sod-meadow soil, where its con-

tent increases to 3.65%.

The $\text{SiO}_2:\text{R}_2\text{O}_3$ ratio in all soils is near 3 and characteristic of hydromica-montmorillonite mineral associations.

The difference between the physicochemical properties of soils in various parts of the flood plain is due primarily to the differential content of the <0.001 mm diameter fraction, where the same mineral of the montmorillonite group predominates and there is an admixture of hydromica. These minerals play an especially important role in soils of areas 2 and 3, where the <0.001 mm diameter fraction amounts to 20%-30%. The mineral of the montmorillonite group promotes the poor permeability of the soils, and their swelling, and determines their high exchange capacity. The admixture of hydromica weakens the effect of the montmorillonite on the decrease in the permeability of soils.

The presence of hydromica everywhere allows one to assume that the soils of the Klyaz'ma River flood plain have a potential supply of potassium, even though the content of available potassium in them is small.

As was established, the main difference between flood-plain soils and the soils of the watershed consists in the considerably greater role played by sesquioxide minerals and amorphous hydrophilic substances in flood-plain soils. They determined the high adsorption of phosphates and affect structure formation. Since the mineral content and the degree of their crystallization differ in various parts of the flood plain, their effect must also differ in intensity.

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ROLE OF SMALL GROUND SQUIRRELS IN THE FORMATION OF COMPLEX SOIL IN CLAY SEMI-DESERT OF THE TRANS-VOLGA REGION

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The influence of small burrowing animals, such as the numerous small ground squirrels (*Citellus pygmaeus* Pall.), on the formation of the microrelief and the complex soil of the Caspian region has interested soil scientists and botanists for a long time (1, 4, 9, 13, 7, 3, 8). The majority, believing that the role of ground squirrels in this process must be very important, stressed the fact that it has not been studied sufficiently. This article is an attempt to determine the importance of the burrowing activity of these rodents in the development of the microrelief and the soil-vegetation complex of Caspian semi-deserts.

We investigated the distribution of inhabited and empty ground-squirrel burrows along the elements of the soil complex, the chemical composition and wetting of soils under the burrows, and also the nature of vegetation on ground-squirrel mounds above the burrows. In addition, instrumental surveys were made of the same burrows during 6 years, which permitted us to follow their gradual "aging".

We made our observations on the burrowing activity of ground squirrels in the clay semi-desert of the Trans-Volga region, primarily in its western part, between the Volga railroad and the Ashche-Uzek River (Gor'kaya), at the base of the Dzhanibek station of the former Forest Institute of the Academy of Sciences of the USSR.¹

The northwestern part of the Caspian lowland, located between the Volga River and the Urals, almost is an ideal plain with a well-defined microrelief and complex soils and vegetation.

A three-member complex predominates on water divides. Microelevations are occupied by solonchak solonchaks, the vegetation of which is represented by meadow grass-black wormwood-goosefoot and meadow grass-black wormwood-goosefoot-saltwort associations. Their slopes

and shallow sinkholes are occupied by solonchaks or leached light-chestnut soils (steppe-like solonchaks) with matricary-wheatgrass-sedge associations, while deeper sinkholes are occupied by dark soils with a grass-mixed herb vegetation (wheatgrass, fescue, feather grass, alfalfa, and steppe mixed herbage and often steppe brush, such as spiraea and almond). Black wormwood solonchaks predominate in this three-member complex, which occupy 50% of the area; areas with light-chestnut, and dark soils with their types of vegetation each occupy about 20% of the area (10, 12).

Small ground squirrels are very numerous in these areas. The number of their burrows averages 150-250 per hectare, and even more in certain places. The mounds of earth ejected from the burrows, which are usually 2-2.5 m across and 15-25 cm high, cover 5%-10% of the area and are an integral element of the microrelief.

The ground squirrels settle primarily in the meadow grass-black wormwood-goosefoot solonchaks, where their burrows are not flooded with melt and rain waters, and where they have a good view of the surrounding area (the only means of protection of these animals). Only 6%-9% of their burrows are found on the slopes of microelevations among the matricary-grass vegetation (6). The animals never settle in sinkholes and only rarely make temporary feed burrows in them.

The ground squirrels dig rather large, deep burrows. The diameter of the nest chamber is 10-15 cm, that of the tunnels, 5-6 cm, the total length of the tunnels below the breeding burrow reaches 3.5 m, and sometimes more (14). The depth of the burrows reaches 1.5-2 m, i.e., they are located in the lower soil horizons and in the subsoil. Usually, several generations of ground squirrels occupy the same burrow for many years. They constantly repair their burrows, dig new tunnels, and fill the old ones. In doing this, the animals turn the soil over, and throw a large amount of soil from the lower soil horizons and from the parent material to the surface, so that a ground-squirrel mound forms at the surface of the burrow. All this leads to substantial changes in the soil, vegetation, and microrelief.

Investigations conducted in southern Ukraine, at Askaniya-Nova (15), and on the high plateaus

¹Soil profiles were described by the scientific head of the station, Prof. A. A. Rode and by M. N. Pol'skiy. Chemical analyses of the soils were made by G. P. Maksimuk and V. Volkova. We followed the advice and instructions of Prof. A. A. Rode while conducting our work.

Table 1

Content of water-soluble calcium and sodium in the top portion of solonetz and solonetz horizons of "virgin" solonetz and ground-squirrel burrows, meq

Depth, cm	Solonetz		Occupied burrow		Abandoned burrow	
	Ca	Na	Ca	Na	Ca	Na
0-10	0,03	0,79	0,5-1,3	0,3	0,18	0,02
10-20	Trace	1,84	2,3	—	0,64	None
20-30	0,05	12,62	5,9	—	3,45	0,09

Note: Comma represents decimal point.

of the Cis-Urals pleneplain in the Aktyuba dry steppes (16), showed that ground squirrels promote the melioration of solonetz, the sub-solonetz horizon and subsoil rich in alkali earth metal salts (carbonates or gypsum), by settling in them. Let us discuss in more detail the characteristics of this process in the solonchak solonetz of the Caspian lowland. The sub-solonetz horizon of these solonetz (its upper boundary lies at a depth of 22-45 cm, and its lower boundary, at 70-105 cm) contains a large amount of gypsum, calcium carbonate, and easily soluble salt, mainly sodium sulfate (2). The parent materials are rich in gypsum.

In digging its burrow, the ground squirrel throws the lower soil horizons and the subsoil to the surface. The soil ejected usually effervesces strongly from hydrochloric acid, which points to its high carbonate content, while solonetz neighboring on the burrow begin to effervesce weakly only from a depth of 16 cm.

The calcium brought to the surface (Table 1) displaces the exchangeable sodium from the adsorption complex of the solonchak solonetz. Easily soluble salts thus formed are rapidly removed from the upper (top portion of solonetz and solonetz) horizons. As may be seen from Table 2, the upper 30 cm of soil in an inhabited ground-squirrel burrow (where the horizon overlying the solonetz and the upper part of the solonetz horizon were ejected) is considerably poorer in easily soluble chlorides and sulfates than "virgin" solonetz.

The rapid removal of easily soluble salts from the ground-squirrel burrow is promoted by its wetting, primarily at the beginning through projected burrows. Samples taken with an auger through profiles passing through a burrow and the adjoining solonetz for moisture determinations showed that lenses with the maximum moisture content are located under projected burrows (Fig. 1). These lenses are small and close to the surface under single burrows. In places, however, where several burrows are concentrated, they reach under the "virgin" solonetz, occupying an area more than 50 cm wide and penetrating to a great depth. This is evidenced by the presence of areas with an increased moisture content at a depth of 200-140

cm under the burrows, which probably represent the traces of past spring wetting.

The vegetation of inhabited burrows differs from that of the surrounding solonetz only in that it is thinner and contains a large number of annuals (*Echinopsilon sedoides*, *Lepidium perfoliatum*, and *Alyssum desertorum*). Goosefoot and black wormwood are often encountered on old, inhabited burrows, which are usually concentrated in the vicinity of old (unused) entrances to the burrows.

For some reason, often the ground squirrels leave their burrow and it remains empty and sometimes is not reoccupied. The soil begins to leach intensively under such burrows. Chlorides are removed in the first place. Only traces of chloride were found in the sub-solonetz and the solonetz horizons under a recently abandoned burrow with very well preserved entrances (Table 2, Profile 176). Only in the upper part of the sub-solonetz horizon, at a level of 40-50 cm, did its content increase to 0.3-0.4 meq, and then decrease again. At the same time the content of less soluble sulfates in the sub-solonetz horizon was still high, even though their maximum dropped from a depth of 30-40 cm to 40-50 cm. All this points to the leaching of solonchak solonetz under the burrow. This is evidenced also by the appearance in the burrow of individual matricary and wheatgrass plants. As may be seen from Table 2, the soil in the root zone of these plants is almost devoid of chlorides most harmful to them.

The content of chlorides under older burrows is less than 0.1 meq throughout almost the entire profile, while sulfates are leached to a depth of 100 cm (Profile 182); only in the upper part of the sub-solonetz horizon do traces of secondary salinization remain. The soil under the burrows changed into strongly leached solonchak solonetz. The process of leaching, caused by the replacement of exchangeable cations in the adsorption complex of the solonetz, and the additional wetting of the soil through the burrows, leads to an increase in the water permeability of the solonetz horizon. This is very clear in Figure 1. Lenses of maximum moisture content in the area of projected burrows have increased approximately five times, have penetrated under

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Table 2

Content of easily soluble chlorides and sulfates in the soil of "virgin" areas and ground-squirrel burrows, meq (soil profile No. in parentheses)

Depth, cm	Type of plants with main root mass at the given depth	"Virgin" areas (2, 10)						Burrows					
		solonchak			light-chestnut soil			occupied (175)			recently abandoned (176)		
		solonetz			dark soil in sink-hole			(182a)			(187)		
		Cl	SO ₄	Cl	SO ₄	Cl	SO ₄	Cl	SO ₄	Cl	SO ₄	Cl	SO ₄
0-10	Fescue, sedge, wheatgrass	0.06	0.37	trace	0.1	trace	0.1	0.05	0.22	0.24	0.02	None	0.38
10-20		0.86	0.12	"	0.05	"	0.08	0.45	0.22	0.50	0.06	"	0.25
20-30	Wheatgrass	4.30	7.60	0.04	0.03	"	"	2.76	1.45	18.21	0.11	0.05	6.94
30-40	Matricary	4.50	28.22	—	—	trace	trace	5.29	2.76	12.11	0.35	0.15	0.89
40-50	Matricary	—	—	0.11	0.06	—	—	4.48	13.75	13.75	0.2	0.10	0.89
50-60	Matricary	—	—	—	—	—	—	3.71	14.44	14.44	0.25	0.05	0.64
60-70	Scattered roots of wheatgrass	—	—	—	—	—	—	5.47	12.42	12.42	0.15	0.10	0.38
70-80	and matricary	4.59	27.93	0.65	1.84	—	—	2.46	14.16	14.16	0.15	0.05	0.64
80-90		—	—	—	—	—	—	—	—	—	—	—	—
90-100	Scattered roots of matricary	—	—	—	—	0.13	0.13	7.81	11.09	11.09	0.10	"	0.89
100-110	"	—	—	—	—	7.97	7.97	—	—	—	0.14	"	13.52
110-120	"	—	—	—	—	—	—	—	—	—	0.25	"	18.24
120-130	"	4.09	25.78	—	—	—	—	—	—	—	—	0.10	20.10
130-140	"	—	—	—	—	—	—	—	—	—	—	0.26	20.20
140-150	"	—	—	—	—	—	0.08	—	—	—	—	0.57	21.25
		—	—	—	—	—	—	—	—	—	—	14.12	0.39
		—	—	—	—	—	—	—	—	—	—	5.23	0.32
		—	—	—	—	—	—	—	—	—	—	0.13	0.38
		—	—	—	—	—	—	—	—	—	0.05	0.17	0.10
		—	—	—	—	—	—	—	—	—	0.30	0.15	0.15
		—	—	—	—	—	—	—	—	—	0.62	"	0.30
		—	—	—	—	—	—	—	—	—	0.75	"	0.50
		—	—	—	—	—	—	—	—	—	0.19	0.64	0.21
		—	—	—	—	—	—	—	—	—	2.08	0.97	0.51
		—	—	—	—	—	—	—	—	—	0.39	"	0.26
		—	—	—	—	—	—	—	—	—	5.23	"	0.75
		—	—	—	—	—	—	—	—	—	0.32	"	—

Note: Comma represents decimal point.

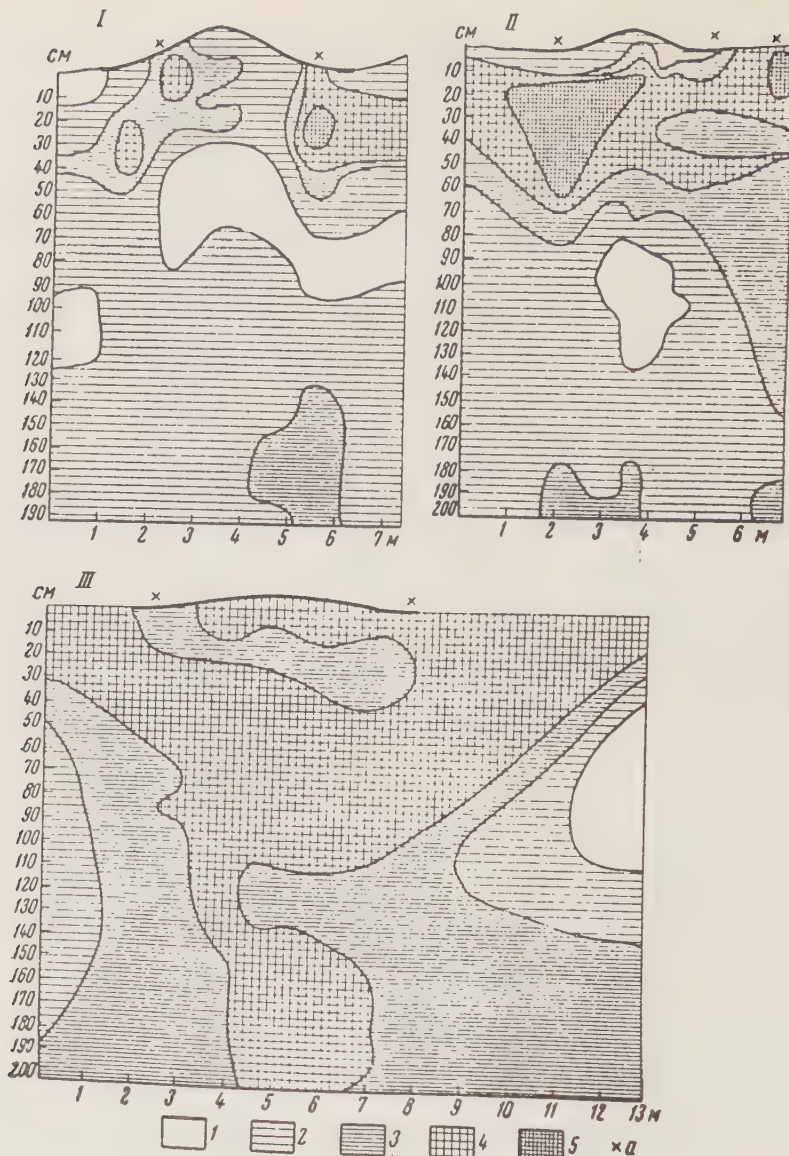


Fig. 1. - Soil moisture under ground-squirrel burrows.

I - inhabited burrow; II - recently abandoned; III - old. Soil moisture:
 1 - less than 13%; 2 - 13%-16%; 3 - 17%-18%; 4 - 19%-20%; 5 - 21% and more;
 a - places with vertical burrows.

the "virgin" solonetz and reached a depth of 60-70 cm under the abandoned, desalinized burrow. A "zone of moderate moisture" (16%-19% moisture), embracing the upper part of the sub-solonetz horizon is located under the entire burrow and the adjoining solonetz, reaching a depth of 90-160 cm under the projected burrows. Thus, soil moisture under the desalinized burrow and the solonetz surrounding it increases noticeably.

The leaching of solonetz and increased soil moisture affect the development of semi-desert and steppe vegetation favorably. At this stage,

a burrow is covered usually by thick matricary with sedge and wheatgrass, while black worm-wood is almost fully displaced.

The desalinized burrow is accompanied by its gradual subsidence. The mound becomes flatter, and wide funnels form in the place of entrances, which often merge into a shallow, semi-circular ditch. These depressions and the well-developed vegetation retain snow, which promotes the deep wetting and further leaching of the soil. The saline profile of soils under very old burrows corresponds to that of leached (steppe-like)

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Table 3

Distribution of desalinizing ground-squirrel burrows and small spots of matricary-sedge associations along the elements of the complex, %

Subject studied	Microelevations, black wormwood associations on solonetztes		Slope of the microelevations, matricary-grass associations on light-chestnut soils	Note
	central part	edge		
Uninhabited burrows in various stages of desalinization	0	72—99	1—28	50-83% are located near old burrows
Flat, closed spots of matricary-sedge associations	20	30	50	

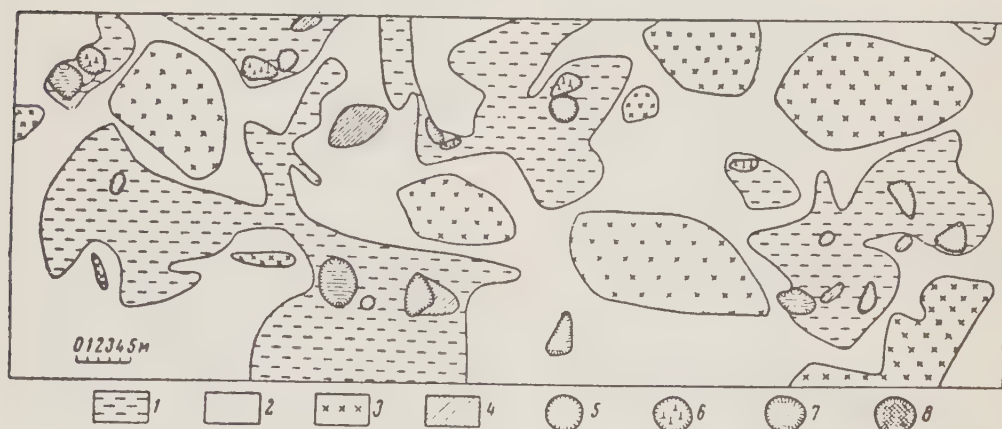


Fig. 2. - Map of the area occupied by small ground squirrels.

1 - microelevations with black wormwood associations on solonetztes; 2 - slopes of microelevations with matricary-grass associations; 3 - sinkholes with grass - mixed-herb associations; 4 - flat spots with matricary-sedge associations; 5 - inhabited burrows; 6 - recently abandoned burrows with black wormwood; 7 - middle-aged burrows with matricary; 8 - old burrows with fescue and wheatgrass.

solonetztes, or even to that of dark soils (Profiles 187, 3, and 183). The soil is very moist under such old burrows (Fig. 1). There are no longer any high-moisture lenses in the

vicinity of projected burrows, while the moist layer (100-110 cm thick) is located under the burrow and its tongues reach under the solonetz (at a distance of 2-4 m from the burrow).

Table 4

Ratio between ground-squirrel burrows of various age groups, %

Land use	Burrow group		
	young	middle-aged	old
Virgin areas	71—77	15—20	8—9
Seeded lowland	55	30	15
Weed abandoned area	60	13	27

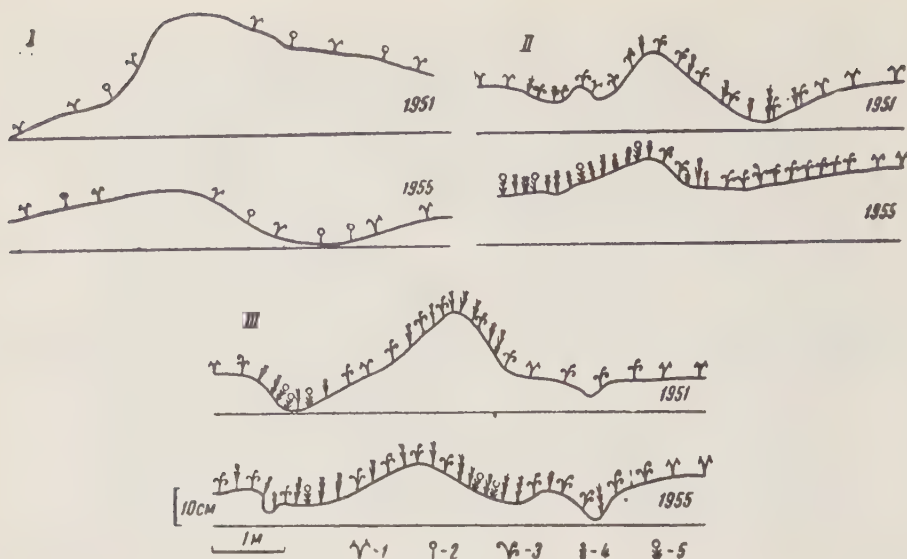


Fig. 3. - Change in the form of ground-squirrel mounds and vegetation on them.

Mounds: I - "young"; II - "middle-aged"; III - "old". Vegetation: 1 - black wormwood; 2 - short-lived plants; 3 - matricary; 4 - wheatgrass and other grasses; 5 - steppe mixed herbage.

Wheatgrass and sedge develop intensely on such old burrows, steppe grasses (fescue and koeleria) and mixed herbage (bedstraw, wormwood, and sawwort) appear and gradually displace matricary.

Thus a flat spot or a shallow depression with light-chestnut or dark soil and the corresponding steppe vegetation form on the solonetz mound where a ground squirrel settled at one time. It is possible that certain small, flat spots of leached light-chnozem soils with matricary and sedge, at the surface of which no signs of a burrow remain, also have formed as a result of the activity of these animals. As the instrumental survey of small plots of the complex level area showed (Fig. 2), almost all abandoned, desalinized ground-squirrel burrows are concentrated along the edges of black wormwood solonetz, frequently infringing on the adjoining matricary-grass associations (Table 3).

In the majority of cases they are very flat and almost do not rise above the solonetz area. At the edges of black wormwood solonetz, usually in the vicinity of old burrows, and sometimes between them, there are small flat spots of matricary and sedge, the dimensions of which approximately correspond to those of the burrows (average diameter of 2.5 m). All this leads to the conclusion that part of them developed in the place of burrows. It is possible also that later these spots merge with the main area of matricary-grass associations, forming tongues reaching into the black wormwood solonetz, or change into sinkholes.

Unfortunately this cannot be proved by extensive material, since the krotovinas almost are unnoticeable in the slightly humic soils of the

Caspian region. However, traces of old ground-squirrel burrows were encountered in certain soil profiles through such flat spots of leached soils or gently sloping sinkholes. As an example we can describe soil Profile 183 which was made through a flat sinkhole with dark soil. In the center of it there is a hardly noticeable mound remaining from a ground-squirrel burrow, while in the profile under the newly-formed humus horizon (0-3 cm) there are remains of refuse (3-7 cm), distinguished by its light color and morphological structure.

The assumption of the zoogenous origin of a number of matricary-grass spots on leached meadow-chestnut soils is confirmed, as we see it, by the data of Ivanova and Fridland (8). Their description of the distribution of flat, enclosed sinkholes with matricary, black wormwood, wheatgrass, and sedge on slightly leached meadow-chestnut soils, and the salt profile of these soils are very similar to that which is characteristic for old, desalinized ground-squirrel burrows. These are distinguished from solonetzic light-chestnut soils by the deeper location of easily soluble salts, the shallower depth of carbonates, and the level of effervescence.

What is the rate (even approximate) of the desalinization of ground-squirrel burrows? We conditionally divided all the burrows studied (about 2,000), both inhabited and abandoned at various times, into three groups: "young" (with a bare summit covered with annuals or stunted black wormwood), "middle-aged" (covered with matricary and a small amount of wheatgrass and sedge), and "old" (with a thick cover of grasses and mixed herbs). To determine the approximate "aging" rate of the ground-squirrel mounds we made annual instrumental surveys of one and the same mounds belonging to the various

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groups, young, middle-aged, and old. This permitted us to follow accurately the gradual changes in the form of the mounds, the entrances to the burrows, and vegetation (Fig. 3). The observations were made from 1951 to 1955. The young burrow was inhabited during the entire period, except in 1953; the two others remained empty.

During the time of observation the young mound flattened greatly (its summit lowered by 20 cm), and acquired gentle outlines primarily because of the compaction of the loose, ejected soil. The vegetation on it changed little. Only in 1954 (after it had remained empty for almost an entire year) did shoots of black wormwood appear at the entrances to the burrows.

The abandoned burrows changed much more. The middle-aged ground-squirrel mound was covered primarily by matricary at the beginning of observation, while the little holes at its edges, where the entrances to the burrows had been, were covered with wheatgrass. The mound decreased 3-7 cm in height within 5 years as a result of subsidence. At the same time the depth of the holes where the entrances to the burrows had been, decreased, the holes became filled and flattened. Also, the vegetation changed noticeably, becoming more steppe-like during the first 2 years (1952 and 1953), which were wet. Wheatgrass became luxuriant on the mound, the amount of white wormwood and bedstraw increased, and matricary began to displace black wormwood around its edges. The next year matricary began to develop over the greatest part of the mound, having choked the grasses and the steppe mixed herbage. And only on the side facing the neighboring sinkhole, vegetation continued to become more and more steppe-like—sedge and fescue appeared, gradually displacing wheatgrass, and the amount of bedstraw increased greatly. Apparently this part of the mound received additional moisture and leaching took place more rapidly there because of the peculiarities of the microrelief.

The old ground-squirrel burrow was a small flat mound at the beginning of observation which was covered with wheatgrass and an insignificant amount of matricary at the summit, and matricary with wheatgrass and a small amount of black wormwood at the edges. It was surrounded by wide, but shallow holes (traces of projected burrows) covered with steppe grasses (koeleria, fescue, sedge, and crested wheatgrass) and mixed herbage. Within 5 years the mound settled noticeably (its summit lowered 15-16 cm), while the holes became filled and merged with each other. Their depth decreased by 5-7 cm. By 1955 this mound became almost level with the surrounding solonetz, being distinguishable from it only by flat depressions in places where the entrances to the burrows had been. The soil and vegetation of the old ground-squirrel burrow became more steppe-like. The grasses (including sedge and fescue) displaced matricary more and more not only from the depressions at the edges of the mound, but also from the mound itself. By 1955 the salt profile of the soil was almost identical to that of the dark soils of the sinkholes (Table 2, Profile 3).

Thus we succeeded in finding noticeable changes in the ground-squirrel mounds even dur-

ing a 5-year period. The considerable rate of this process also is confirmed by other data. As we know, ground squirrels damage grain crops greatly. In the semi-desert clay of the Trans-Volga region plantings are concentrated almost exclusively in lowlands with dark soils. The animals are constantly being exterminated around these areas, so that they contain an especially large number of abandoned, desalinized mounds. It is clear that the more time passes from the moment the lowland is plowed, the further the "aging" and desalinization of ground-squirrel burrows goes. A comparison of the ratio between ground-squirrel burrows of various ages in virgin areas, near settlements, and around areas covered with weeds (Table 4), showed that in about 20 years, from the moment the lowland had been plowed to the time it became overgrown by weeds,² about half of the abandoned ground-squirrel burrows became desalinized and covered with grasses, i.e., they changed from the middle-aged to the old group (17).

From the foregoing the conclusion is easily reached that ground squirrels promote the desalinization of solonchak solonetz and that this process is rather rapid. Taking into account the large population of these animals, it is easy to see the scale of their activity. Their role in the change of the complex soil of the Caspian lowland is directed toward its general evolution, i.e., desalinization and desolonetzization (11, 8). Because ground squirrels always settle on solonetzic microelevations, i.e., in areas of maximum salt concentration, eventually they cause their desalinization and the destruction of these seats of salinization. The desalinization of the upper soil horizons, an increase in soil moisture, and a slight desolonetzization take place even in inhabited ground-squirrel burrows, where fresh portions of soil are constantly ejected. After a burrow has been abandoned, these processes continue with a great intensity and rapidly lead to the formation of a flat spot of light-chestnut soil in the middle of a solonetz mound, and later, probably to the formation of a sinkhole with dark soil.

However, the role of ground squirrels in the desalinization of soils in the Caspian region should not be over-evaluated. It must not be forgotten that the animals very often reoccupy their abandoned burrows, preferring to renew them rather than dig new ones. In doing this they usually occupy comparatively recently abandoned burrows, which are not yet overgrown by dense herbage.³ As we have seen, the soil of such burrows consists of variously leached solonchak solonetz, in which the chlorides have been removed to a great depth, while sulfates are still in the sub-solonetz horizon, i.e., within depths reached by ground squirrels. When renewing the burrow the animals throw these salts out on the surface, thus slowing down the further leaching of solonetz. Observations showed that occupied burrows (including those which have been salinized a second time) comprise 80% of the total number of burrows. Only in places

²The lowland is usually seeded for 10-12 years, while the stage when weeds are allowed to grow does not last more than 4-5 years.

³Observations showed that of the recently abandoned burrows 37% were reoccupied, of the middle-aged, 25%, and of the old ones, only 4% (6).

where the animals are constantly being destroyed does the number of occupied burrows drop to 63%. The number of abandoned, desalinized burrows changes correspondingly. Their number about doubles in areas of intense human activity, whereby middle-aged burrows comprise 25% of all burrows, and old burrows, 12% (in areas with less human activity they comprise 12% and 9%, respectively).

As far as the effect of the burrowing activity of the ground squirrels on microrelief is concerned, their role is twofold. In settling in solonchak solonchaks, they promote the formation of a secondary microrelief on them, and increase the diversity of soils and vegetation; higher ground-squirrel mounds appear among the solonchak solonchaks, as well as flat spots of light-chestnut soils and sinkholes with dark soil and a steppe-like vegetation in the areas of old burrows.⁴

At the same time, on the scale of the general evolution of the soil and vegetation of the Caspian region, ground squirrels promote the leveling of the microrelief and a decrease of the complexity, since solonchak areas gradually decrease and leached zonal soil with a steppe-like vegetation increase because of their activity, which is characteristic of the evolution of the complex soil and vegetation of the Caspian region (8).

However, as may be seen from the material presented, the desalinization and desolonchization of soil under the influence of the burrowing activity of these rodents proceeds very slowly on the scale of the general trend of desalinization of soils in the Caspian region. This is why ground squirrels cannot play the leading role in the evolution of the complex soil and vegetation of the Caspian region. They only accelerate it, which is especially noticeable in regions where the animals are constantly being destroyed over wide areas.

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⁴Precisely this aspect of the activity of ground squirrels was meant by Formozov, Khodashova, and Golov (17), in an article on the effect of burrowing animals on microrelief and the complexity of soils and vegetation in the Caspian region.

NATURE OF THE CHANGE IN PEAT
UNDER THE INFLUENCE OF AERATION

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When peat bogs are reclaimed for agricultural crops, their upper horizons undergo rather rapid and deep changes mainly under the influence of increased aeration. These changes have been studied little, while they are of scientific and practical interest. Their study is rather complicated and requires various methods and particularly laboratory experimentation.

The authors had the opportunity to conduct such an experiment on peat samples kept in the laboratory of the Central Peat-Bog Experiment Station for 13-15 years. These samples were collected from 1944-1946 in the "Galitskoye" and "Lodkinsiy mokh" peat beds in the Kalinin Oblast'. The samples were taken from special trenches and kept at room temperature in 25-liter jars of dark glass. The jars were covered

with wooden stoppers, which did not close them hermetically. The upper peat layers became dry from time to time so that distilled water was added to the jars. It was found in recent years that the upper peat layers, 0.5-1.5 cm thick, differed sharply from the lower layers by their dark color and structurelessness.

Investigation of the upper and lower layers of four peat samples showed that there were sharp morphological (Figs. 1-3) as well as chemical differences between them.

Two of the samples studied consisted of upland, slightly decomposed sphagnum peats. The third sample consisted of strongly decomposed upland cotton grass peat, and the fourth sample, of slightly decomposed sedge-hypnum lowland

Table 1
Chemical composition of the lower and upper layers of peat in the samples studied

Sample Number	Type and variety of peat	Sample layers	Degree of com- position	Ash con- tent	pH (KCl)	N in %	Group composition of organic matter, %						
			in %	Substances soluble in alcohol			Substances soluble in benzene	Humic acids	Fulvic acids	Easily hydro- lyzed sub- stances	Cellulose	Non-hydro- lyzable resi- due	
1	Upland sphagnum, boggy	Lower	5	3,04	3,00	0,83	3,93	0,1	8,96	10,81	53,54	11,52	10,62
		Upper	21	6,58	3,22	1,61	4,86	0,42	19,68	12,18	39,29	13,62	9,95
2	Upland medium	Lower	17	2,37	3,20	1,47	12,63	0,29	17,67	6,88	43,88	4,48	14,17
		Upper	27	3,98	3,29	1,89	11,72	0,52	34,92	7,48	32,29	3,72	9,41
3	Upland cotton-grass	Lower	47	2,09	2,93	1,30	7,58	3,03	50,19	6,84	10,34	1,50	20,70
		Upper	55	2,38	3,04	1,47	10,02	5,53	51,26	4,27	9,13	1,43	18,18
4	Lowland sedge - hypnum	Lower	15	6,01	—	1,91	4,55	0,81	12,37	10,73	35,41	7,73	28,40
		Upper	28	8,83	—	2,75	3,20	0,83	27,04	8,24	28,39	7,15	24,15

Note: Comma represents decimal point.

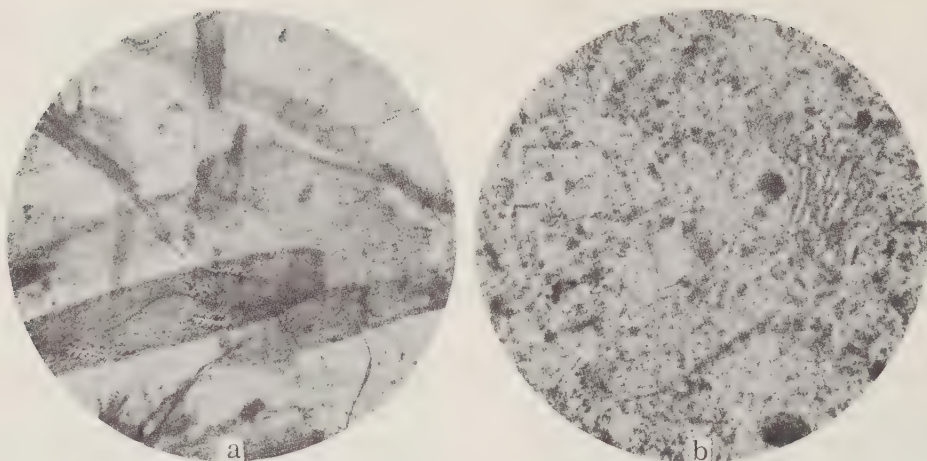


Fig. 1. - Microphotograph of sample No. 1. Magnified 45 times.

a - lower, unaltered peat layers. The branch leaves of sphagnum mosses are clearly visible, there is little humus; b - upper peat layer which has changed under the influence of aeration. The leaves of sphagnum mosses are strongly decomposed; there is a large amount of humus.

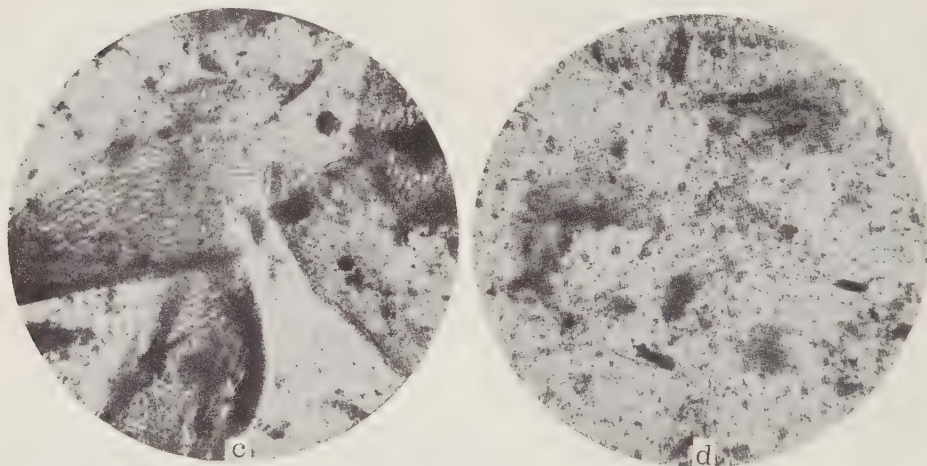


Fig. 2. - Microphotograph of sample No. 2. Magnified 45 times.

a - lower, unaltered peat layers. The leaves of sphagnum mosses are partly decomposed; b - upper peat layer which has changed under the influence of aeration. Small fragments of sphagnum mosses, bark fragments, and a large amount of humus are visible.

peat.

Table 1 gives the results of analyses. They show the changes in the decomposition, ash content, pH (KCl), nitrogen content, and the group composition of organic substances, as determined by the method developed by Dragunov (2).

Microscopic examination of the peat samples showed that their upper layers underwent great changes. They were most noticeable in slightly decomposed upland peats, where the relative

content of cotton grass and pine residues increased and the amount of sphagnum mosses decreased. An analogous picture was observed by Belikov (1) when peat was produced artificially during humification.

A large number of pollen grains and spores, fungal hypha and a very large accumulation of microorganism remains, primarily of a coccus-like nature, were found in the upper layers of the samples studied.

The relative accumulation of residues of

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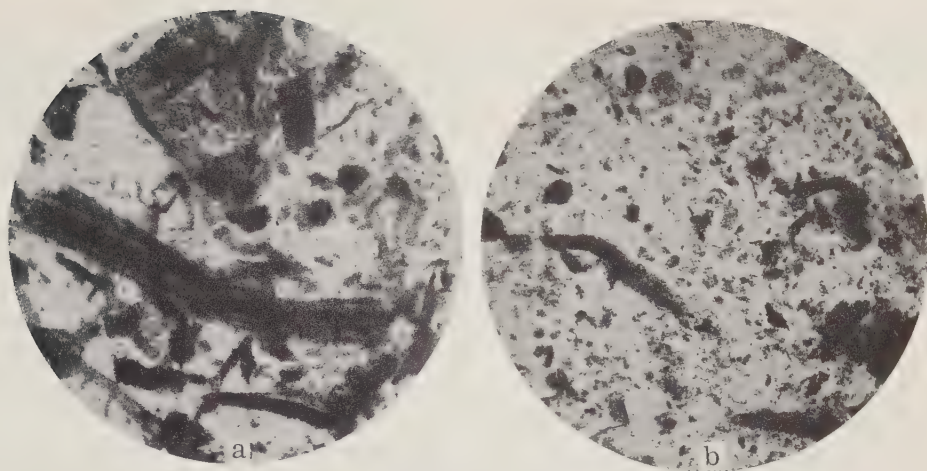


Fig. 3. - Microphotograph of sample No. 4. Magnified 45 times.

a - lower, unaltered peat layers. Residues of hypnum mosses and sedges are visible, there is little humus; b - upper peat layer which has changed under the influence of aeration. The remains of hypnum mosses and sedges are pulverized, there is a large amount of humus.

cotton grass, pine, and tree pollen, is the result of the more rapid decomposition of sphagnum mosses, the organic substances of which include a larger amount of easily hydrolyzed material. Similar results were obtained by Kononova (3) in her study of the humification of plant residues.

The morphology of plant fiber underwent great changes. This was very noticeable in the first sample, the lower layer of which consisted 95% of residues of sphagnum moss of the *Cuspidata* (primarily *Sphagnum cuspidatum* and *Sph. balticum* as an admixture to *Sph. recurvum* and *Sph. angustifolium*), 2%-3% of remains of *Sph. medium*, and only 2%-3% of roots of the heath family and cotton grass, and fragments of pine bark. The residues of sphagnum mosses were represented primarily by branch leaves and to a lesser degree by the residues of stems and branches. Stem leaves were also encountered. The structural elements were well-

expressed, the edges were almost undisturbed, and the spiral bulges on leaves and the hyalodermis of the stem were well preserved.

There was less than 80% of sphagnum mosses, 10%-15% of cotton grass residues, and about 5% of pine bark and wood in the upper layer of this sample. As a whole, undisturbed macerations of sphagnum moss leaves remained, and stem leaves were represented by small residues. The amount of stem residues had increased considerably; they were strongly pulverized, torn, and lacked a hyalodermis.

The leaves of *Sphagnum medium* (predominating and *Sph. angustifolium*) were slightly decomposed and fully retained their structure in the preparation from the lower layer of sample No. 2. Only bits of branch leaves of *Sph. medium* and *Sph. angustifolium* were found in the preparation from the upper layer of the same sample together with bits of stems, masked by very small

Table 2

Changes in the fractions of organic matter and nitrogen of peat under the influence of prolonged aeration, % of initial amount

Sample Number	Losses of organic matter, % of initial amount	Alcohol-soluble substances	Benzene-soluble substances	Humic acids	Fulvic acids	Easily hydrolyzable substances	Cellulose	Non-hydrolyzable residue	Nitrogen
1	50	-40	+50	+10	-40	-60	-40	-50	0
2	40	-40	+10	+20	-35	-60	-50	-60	-20
4	20	0	+50	0	-40	-30	-20	-30	-10
5	30	-40	-20	+50	-40	-40	-30	-40	0

Table 3

Change in the ash content of peats depending on their degree of decomposition

Degree of decomposition, %	Ash content, %	
	Upland	Lowland
0—10	1,40	4,09
11—20	1,44	4,93
21—30	2,2	7,25
31—40	2,29	7,90
41—50	2,46	8,74
51—60	2,85	9,10
61—70	3,58	9,56

Note: Comma represents decimal point.

humus particles, root fragments of the heath family, and a large number of pollen and spores. About 50% of the *Sph. medium* leaves were undecomposed, or decomposed only partially in the washed fiber in the lower layer of this sample. Eight percent of stem leaves, and two-thirds of the stem residues had a preserved hyalodermis with well-expressed fibers and pores. Only one-sixth of the stems in the washed fiber from the upper layer had a preserved hyalodermis. No whole sphagnum leaves were found, only their small fragments predominated.

Morphological changes proved insignificant in sample No. 3 which consisted of well-decomposed upland peat.

Sample No. 4 consisted initially (1946) of the hypnum moss *Meesea triquetra* (75%) and sedges (20%), primarily *Carex lasiocarpa*, *C. rostrata*, and *C. limosa* with a small admixture of other peat producers. At the present time the botanical composition of its upper and lower layers consists of the following.

The residues of hypnum mosses comprise 70%–80%, and those of sedge mosses, 20% in the lower layer. Thus the peat of this layer has not changed in 15 years. The upper layer consists 60%–65% of *Meesea triquetra*, 5% of *Drepanocladus* sp., 30% sedges (*Carex lasiocarpa*, *C. rostrata*, and *C. limosa*, and single cotton grass, *Sph. subsecundum*, *Sph. teres*, and rush. There is a decrease in hypnum moss remains and a relative increase of sedges.

A considerably greater difference is found in the nature of the fiber. Partially decomposed leaves of *Meesea triquetra* and stems with leaves comprise 50% of the total mass of the residues of this moss in the lower layer, while in the upper layer they comprise only 16%. Almost all the leaves of *Meesea* are green in the lower layer, the cells are clearly outlined, both the upper and lower part of a leaf are often preserved, and bent back along the ribs, or the entire leaf is bent together along the rib. The sedge roots have clearly defined edges with well-preserved cells by which root hairs are at-

tached, while *Carex limosa* has retained a large amount of root hairs. In the upper layer, *Meesea triquetra* leaves are found mostly in the form of individual fragments. Only a small amount of the residues is green, most of them are slightly brownish, and the cell structure has lost its clarity. The stems of hypnum mosses are torn and rarely the leaf blades are found with veins. The latter are split into fragments, as the stems are.

The roots of sedges, particularly those of *Carex limosa*, are torn, there are very few root hairs and they are torn from the roots. The smaller residues found in unwashed peat have poorly defined, "diffuse" edges. The internal structure of cells is poorly distinguishable, there are many very thin films with an indistinct structure which makes it difficult to determine to which type the residues belong.

Thus our investigations showed that essential morphological changes occurred in the upper layers of the sample studied: the structural elements of the tissues became greatly decomposed and a relative accumulation of those plant residues which have a high biochemical stability took place. These changes were especially pronounced in slightly decomposed peats, while they were weakly pronounced in well-decomposed peats.

Let us examine the data on the chemical composition of peat in the upper and lower layers of the samples studied, which are given in Table 1. The data point to a considerable change in the composition of peat in the upper layers as compared to the lower layers. Let us note, by the way, that the lower layers remained practically unchanged for 15 years, namely: the degree of decomposition of peats Nos. 1, 2, and 3 was 3%, 15%, and 45%, respectively, in 1944, and the ash content was 3.17%, 2.60%, and 2.10%.

In contrast to this, the difference between the upper and lower layers is quite considerable. Let us note that these differences are very pronounced in slightly decomposed peats, and little noticeable in well-decomposed peats. This conclusion agrees with data obtained from the study of the morphology of the peats.

The degree of decomposition increased by 10%–15% in all peats, and in sample No. 1 it increased from 5% to 20%, i.e., more than four times. The ash content increased more than two times (from 3.04% to 6.58%) in the first sample. The changes in the ash content make it possible to determine the losses of the organic substance of peat. Calculations showed that the losses were 50% in the upper layer of the first sample, 40% in the second sample, 20% in the third sample, and 30% in the fourth sample.

The acidity of various layers of upland peats practically remained the same. This agrees well with the fact that the absolute amount of bases, which are an important factor in the acidity of peat, changed only slightly as a result of the mineralization of peat.

It may be seen further from Table 1 that the upper layers of peat became enriched with nitrogen, bitumens, and humic acids; at the same time their content of easily hydrolyzed substances and non-hydrolyzable residue decreased. The

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other fractions of organic substances changed less.

Since all these changes took place against a background of losses in the organic substances of peat, corresponding corrections were made to determine the true nature of the changes, the results of which are given in Table 2. The data show that most fractions of organic substances became mineralized under the influence of aeration, whereby the intensity of mineralization was similar for the various fractions. The only exception being fractions extracted with benzene (bitumens), the absolute amounts of which increased noticeably in upland peats, and humic acids which greatly accumulated in lowland peats. The amount of nitrogen did not change substantially. Let us point out that this conclusion agrees with data obtained by Waksman (6) under conditions similar to ours.

The data obtained allow us to differentiate between processes taking place during the drainage of peat and during peat formation. As can be seen from the foregoing, the plant fibers in peat decompose under the influence of aeration; parallel with it a certain accumulation of bitumens and humic acids, and the intense mineralization of most of the fraction of organic substances take place. It must be emphasized that the increase in the degree of decomposition in this case is accompanied by a sharp increase of the ash content of peat.

The collection of peats at the Central Peat-Bog Experiment Station, which embraces various regions of the European USSR (5), allowed us to detect the relationship between the degree of decomposition of various peats and their ash content.

The results obtained by corresponding analyses of data for more than 300 samples are given in Table 3. Only samples of peats with a "normal ash content," i.e., devoid of ash brought from the outside, were used for the calculations.

The data show evidence of a relationship between the degree of decomposition of peat and its ash content: with an increasing degree of decomposition the ash content increases very gradually.

We must consider that the given data reflect the influence not only of the degree of decomposition of peat, but also of the initial characteristics of vegetation groups on its ash content. If slightly decomposed peat consists of mosses primarily, then strongly decomposed peat usually consists of woody plants. At the same time it is well known that woody plant groups deposit peats of a higher ash content than do mosses under otherwise similar conditions. Because of this the effect of the degree of decomposition of peat on its ash content is actually smaller than it follows from the presented data. In comparing them with data obtained for peats which have been subjected to aeration, we will find considerable differences between them. If in the first case the ash content doubles with a degree of decomposition of 50%-60%, in the second case it requires an increase in the degree of decomposition of only 10%-15% in order to double.

Thus peat formation is accompanied by an insignificant loss in organic substances, while the modification of peat under the influence of aeration is accompanied by intense mineralization.

Conclusions

1. Rapid and great changes occur in peat layers under the influence of aeration, which are reflected both in its morphology and composition.

2. The plant fiber becomes decomposed in peat, whereby peat becomes enriched in biochemically stable elements because of the differential rate of decomposition of various plant residues.

3. Parallel with the increase in the degree of decomposition of peat, its ash content increases because of the mineralization of its organic substances, as evidenced by morphological indices. These processes are more intense in peats which initially have a low degree of decomposition, and are slower in well-decomposed peats.

4. With the exception of bitumens and humic acids, the content of all other fractions of the organic substances of peats (substances extractable with alcohol, fulvic acids, easily hydrolyzed substances, cellulose, and non-hydrolyzable residue) decreases similarly, primarily because of mineralization.

5. The peats become enriched in bitumens and humic acids, whereby in many instances not only a relative enrichment occurs, but an absolute accumulation of these substances.

6. The intense mineralization of organic substances is not accompanied by any substantial losses of nitrogen, so that peat becomes enriched with it under the influence of aeration.

7. Processes taking place in aerated peat layers are morphologically similar in many respects to processes of peat formation, but differ greatly from them by the nature of the changes in the chemical composition of organic substances. If in the first case the decomposition of plant fiber is accompanied by the intense mineralization of organic substances and by only a slight accumulation of humic acids, then during peat formation humification proceeds without significant losses of organic matter.

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NUMBERING RELIEF FEATURES DURING SOIL INVESTIGATIONS

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As a result of current soil investigations in the Brest Oblast', accurate and scientifically-substantiated cartographic material has been obtained which characterizes farm soils. Such material includes a soil map and cartograms of the acidity, and the amount of available phosphorus and potassium in soils. The accuracy of these documents depends on how the profiles are tied to relief elements and situations.

To simplify the field work of soil scientists (with a topographic map), all relief features of

field investigations and working out of recommendations. Usually the work is done almost a year after field investigations so that the recommendations made are generalized and have no practical sense.

The same can be said of other land uses. The numbering of relief features will be of help in these cases, too. It is not necessary to make final recommendations in the field, but it is important that each relief feature be described when keeping records, such as the following:

No. of relief feature on the map	Land use	State of the land use	Productivity	Means of improvement	Further use
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a location must be recorded and numbered, in addition to topographic notations. This will allow accurate orientation in the areas and would greatly facilitate the tying in of profiles. Under conditions of small relief features, typical for the Belorussian SSR, tying in of profiles to the boundaries of the feature may prove to be uncertain, for instance, tying in of a profile by numbers in a small area in a field located in the middle of a forest.

In the Brest Oblast' relief features of unknown origin, the soil of which is hardly distinguishable from the remaining massif, are often found in the middle of a field. These features interfere with the mechanical work of seeding and the introduction of complex mechanization; usually they can easily be transformed into plow land. But this transformation cannot always be achieved. Thus, one must determine the measures for improving each area directly in the field. There should be no discontinuity between

The records must be kept not only by the soil scientist making the investigation, but also by other specialists in the group, who, having a map with the same numbering of relief features, can describe these and make recommendations, which can be generalized during analysis in the office. Using the records it is easy to compile a cartogram of the rational utilization of lands; the cartogram is necessary because one cannot judge from a soil map of the possibilities of transforming one or another relief feature, and consequently plan the reclamation of new lands, without additional examination.

A cartogram with soil groups arranged according to agricultural productivity would be a valuable asset for intra-farm management; it will facilitate the analysis of proposed, or used crop rotations, and disclose unused possibilities.

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CAPILLARY METHOD FOR STUDYING MICROBE DISTRIBUTION IN SOILS

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The most common method of microbiological soil investigation is the method of growing microorganisms on solid nutrient media. This method has been criticized severely by Vinogradskiy (1). Greater attention should be paid to the problem of studying soil microbes in their natural associations. The method most widely used for this purpose is the method of growth glasses, which was proposed by Kholodnyy for soils (10, 11). The principle of this method boils down to the microscopic study of fixed and stained microbial growths forming on glass slides (on cover glasses in Russia), placed in the soil for various periods of time (days and weeks). The method of growth glasses has been proposed earlier for clays by the hydrobiologist Naumann (12, 13).

The method of growth glasses appealed to investigators because of its simplicity and the possibility it offered to see at least part of the soil microbes in their natural surroundings. It was used widely in the 1930's in various investigations, but then it lost some of its interest. In addition to the impossibility of isolating pure laboratory cultures of individual representatives of microbial biocenoses developing on growth glasses, the imperfection of these procedures became more and more evident.

However, the study of soil microflora in the microbial situation is still essential because the culture method discloses only an insignificant part of the microflora inhabiting the soil, even on various synthetic media, while its study in pure cultures often gives an incomplete, and even distorted idea on the natural life cycles and physiology of the isolated microbes.

Therefore, it is not surprising that the method of growth glasses is sometimes used to this day to solve certain problems in studying the microbial situation.

Recently Rybalkina and Kononenko (7, 8, 9) turned to the method of growth glasses. They showed that in perfecting this method one may discover the active microflora of soil and separate it from the potential microflora; the latter consisting of numerous microorganisms which are inactive and in a state of rest at the given moment. As these authors point out (8), the study of microscopic images appearing on growth glasses "gives the possibility of observing the simultaneous development of various

microorganisms, their state, the ratio between individual forms, and their interrelationships." "In our opinion," writes A. V. Rybalkina (7), "the method of Kholodnyy should not be ignored at this time, there are still many possibilities of improving it." To improve the method it has been proposed, first of all, to coat the glass slides with a thin film of an agarized medium, free of dead microbial bodies. In absorbing moisture, the agar enhances the ability of the glasses to be covered with growth, which is especially pronounced under conditions of deficient moisture, such as in southern chernozems. Secondly, in studying the microflora of excessively wet and fine-textured soils, it is recommended that the glass be wrapped in a thin layer of glass cloth before being placed in the soil to prevent the agarized surface from becoming contaminated with fine soil particles.

A new principle of studying natural micro-organism associations inhabiting natural media has been proposed by Perfil'yev (2, 3, 5), who showed that as far as the distribution of microflora is concerned, "muds and submerged soils, as well as sedimentary rocks, are capillary, circulating, stratified systems of microgrowths." The main habitat of their microorganisms in soil is the surface of its solid particles which are constantly being washed with water in the soil capillaries.

Considering this situation, we found it necessary to replace growth glasses by thin glass capillaries when studying the soil microflora in its natural habitat. But ordinary glass capillaries are unsuitable for this purpose because of the cylindrical form of their walls which interferes with microscopic examination.

Using the capillary glass making technique, developed by Perfil'yev and his collaborators (5), we succeeded in creating glass capillaries of a new type with flat walls, with rectangular channels or channels of another form, and with various numbers of channels in one capillary.

For studying the microflora of mud, Perfil'yev (4, 5) proposed a simple, new device, the capillary peloscope, consisting of a bundle of flat capillary cells made of glass with rectangular channels fastened to a holder.

The use of this device in the study of the microflora of bottom deposits of a number of

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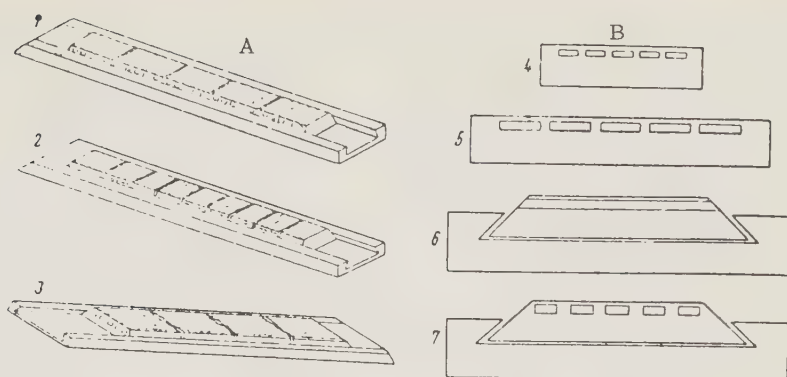


Fig. 1. - Capillary pedoscope.

A - general view of various types of capillary pedoscopes: 1, 2 - type with capillary cells, the channels are oriented perpendicularly to the axis of the holder; 3 - type with longitudinally arranged channels in the capillary cells. B - cross section of capillary cells of the pedoscope and of the holder: 4, 5 - capillary cells of the first type; 6 - holder in cross section with capillary cells of the first type; 7 - capillary pedoscope with longitudinally oriented cells in cross section.

fresh-water reservoirs led Perfil'yev to the discovery of more than 30 new, unusual species of microbes (4, 5, 6). It proved that among the clay microflora microorganisms are often found which move along solid surfaces, i.e., creep. They are not disclosed at all by the method of growth glasses, since on growth glasses all that moves, as well as that which does not move, is equally fixed on drying even before microscopic examination. In addition, a considerable part of moving microbes is lost when the glasses are removed from the mud.

Only by means of the pedoscope is it possible to discover and convincingly show the leading role of several very unusual species of bacteria in the deposition of manganese and iron ore (5).

However, the capillary pedoscope is suitable only for muds and soft bottom deposits. For more compact, loose soils Perfil'yev and Gabe constructed a pedoscope, the name of which indicates the application of this device to soils. As may be seen from Figure 1, the pedoscope consists of a set of capillary cells, set in the grooves of a holder. Each cell has 5 rectangular channels, arranged in a row under a thin flat cover, and a thicker bottom. The holder is made entirely of glass and consists of a channel 70 mm long, 9-11 mm wide, having a flat bottom and side walls set at an angle of 45° . The foregoing is explained by the diagram showing the holder in cross section (Fig. 1-6, 7). One end of the holder is wedge-shaped and has a transverse partition to prevent the cells from slipping out of the groove. The number of the holder is written on the opposite end. If the surface of the holder is frosted, the number can be written in pencil. If the surface is smooth, the numbers are written with India ink and covered with BF-2 glue and the holder is placed in a drying box at a temperature of 170°C . The glue polymerizes under the influence of the high temperature and its film becomes water-impermeable.

In the various versions of the pedoscope, the

channels of the capillary cells may be oriented either perpendicularly to the axis of the holder, or parallel to it. In the first case (Fig. 1-1, 2, B) both ends of each cell must be ground to an angle of 45° , and their length must correspond to the width of the groove of the holder, insuring a hold in the form of a "swallow's tail." The configuration of the capillary cells in this version of the pedoscope is shown in Figure 1-4, 5. One holder can accommodate from 5 to 10 capillary cells, depending on the width of the latter. In our work we used primarily cells of 2 sizes: 5-6 mm wide with channels 0.65×0.20 mm in cross section, and 8-10 mm wide with channels 1.0×0.3 mm in cross section.

In the pedoscope with the channels of capillary cells arranged along the groove of the holder, the side walls of the cells must be slanted at an angle of 45° , and the width of the cells must correspond to the groove in the holder (Fig. 1-7). The ends of the cells in this version must be cut at a slight slant, so that they fit closely together when inserted in the holder and the channels easily penetrate the soil solution.

In inserting the pedoscopes into the soil, they must be arranged in such a manner that the

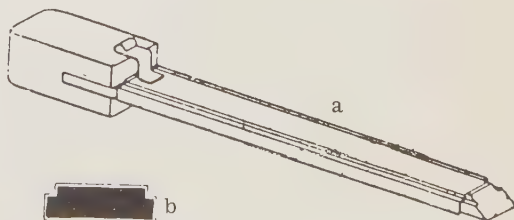


Fig. 2. - Metal puncher in the casing for inserting capillary pedoscopes into soil.

a - general view; b - cross section

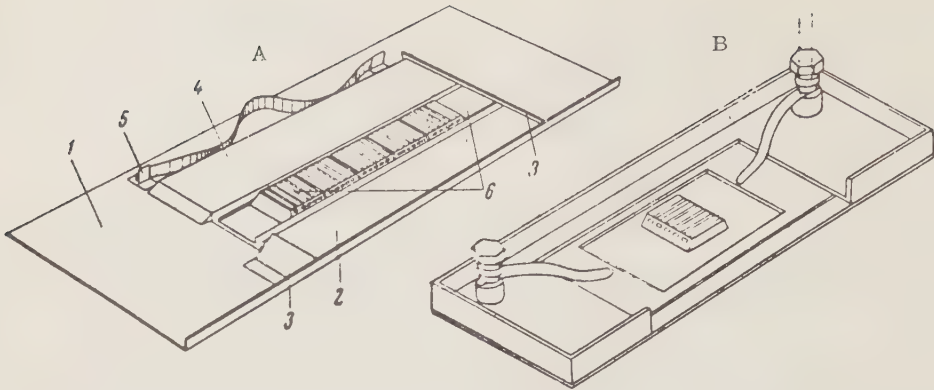


Fig. 3. - Device for the microscopic examination of pedoscopes.

A - stage for examining pedoscopes containing living material; 1 - lower plate of the stage; 2 - glass bar, fastened by metal flanges 3; 4 - removable glass bar, clamped to the pedoscope 6 by a spring 5. B - metal frame for thin slides for the microscopic examination of capillary cells with an immersion lens.

channels of the cells are vertical, i.e., in the prevailing direction of movement of the soil solution. This is why pedoscopes with longitudinally oriented channels must be placed in the soil vertically, while the pedoscopes with transversely arranged channels are placed in the soil horizontally. It must be noted that the version of the pedoscope with longitudinally oriented channels is simpler to manufacture, however it is suitable only for the study of the microflora of the upper 5-7 cm of soil. The other version of the pedoscope with transversely oriented cells is more effective for the study of soil microbiology, since it can be placed in any horizon of the soil profile.

The pedoscope is inserted in loose, coarse-textured soil without the aid of auxiliary equipment, since the sharp, wedge-shaped end of the holder easily makes way for the capillary cells under slight pressure. But the glass holder may break if it is forced into non-cultivated soil,

compact sand, clay, etc. In this case a metal device must be used which consists of a steel puncher, tightly set in a thin-walled casing with an opening. The cross section and length of the puncher correspond to the outer configuration of the pedoscope, and this is why the latter fills the opening of the casing of the puncher (Fig. 2).

The puncher is used in the following way. First a puncher of the required size is selected, i.e., such a puncher through which the casing of the given version of the pedoscope may be inserted easily (holder with the set of capillary cells). Since shaped glass holders which are the product of drawing vary somewhat in width (from 2-3 mm), 2 punchers of varying widths must be available.

To insert the glass pedoscope into compact soil without disturbing their structure much, the puncher with the casing is first driven into the soil. Then, holding the casing in the soil by its

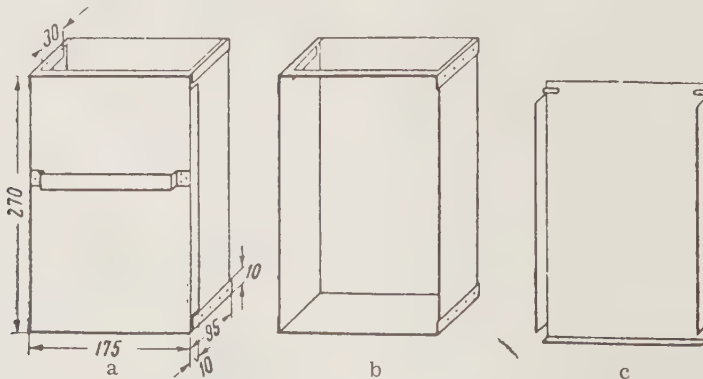


Fig. 4. - Greenhouse pot with a removable front wall for using capillary pedoscopes under laboratory conditions.

a - assembled pot; b - same pot without a side wall; c - side wall with clamps for holding the glass.

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bent handle, the puncher is withdrawn from it and the pedoscope is inserted into the casing with the sharp end forward. To withdraw the metal casing from the soil, the end of the puncher must be propped against the pedoscope and, holding the pedoscope with it, the casing is withdrawn from the soil.

To examine the contents of the capillary cells in a living state, the pedoscope is put under a microscope as soon as it is withdrawn from the soil. To decrease the evaporation of moisture from the capillary cells with transversely oriented channels, a special stage of a simple construction is recommended (Fig. 3—A). The stage consists of a thin rectangular tin plate with a longitudinal rim. There is a long, narrow slot in the center of the plate which is closer to one of its edges and corresponds to that part of the holder which houses the capillary cells. Two glass bars are located at the edges of the slot, parallel to its longitudinal axis. One of these is secured in grooves along the edge of the plate, the other can be moved by means of spring clips. After placing the holder with the pedoscope cells over the slot in the plate it is clamped by a spring between the fast and movable bars. Each of the bars is covered by a long glass plate of trapezoidal cross section, the width of which slightly exceeds that of the bars. As a result, the slanted edge of the plate protrudes slightly over the edge of the bars and 2 narrow channels form at the ends of the transverse cells. If these are filled with water, evaporation from the channels of the capillary cells ceases. The pedoscope with the longitudinally oriented capillary cells does not require the foregoing device when it is being examined.

To study the microflora developed in the cells of the pedoscope in more detail, immersion lenses are needed, which requires a working clearance of the microscope condenser of about 1 mm. Because of the thickness of the bottom of the capillary cells of the pedoscope (a thin bottom makes it more difficult to secure the latter in the holder), when examined under the microscope they must be placed on slides as thin as possible. For the latter we suggest the use of rectangular pieces of thin glass plates (0.2–0.3 mm), 40 x 18 mm in size, which are easily obtained by drawing the corresponding material from sheet glass. The capillary cells can be mounted with Canada balsam on these miniature slides. To move the thin slides on the microscope stage by means of the mechanical stage, they are inserted in a metal frame (Fig. 3—B). The latter is a rectangular metal plate, 0.3–0.4 mm thick, and of the same size as the slide; it has a rectangular slot in the center through which the specimen is illuminated. The glass is held in the slot by a pair of spring clips. There are vertical flanges at the edges of the metal frame, so that it is securely fastened in the mechanical stage of the microscope, similar to an ordinary slide.

We find the capillary pedoscope useful not only under natural conditions, but also under laboratory conditions, where the water and temperature, which play an important role in the development of soil microflora, are more easily controlled.

For this purpose we recommend the use of a

greenhouse pot with one removable wall (Fig. 4). It consists of a rectangular box without a lid, about 95 x 175 x 270 mm in size, made of sheet iron and covered with anti-corrosion paint. The possibility of corrosion may be reduced by isolating the soil from the iron by rectangular glass interlayers, cut from window glass and inserted in the metal box in a definite order. The wide front wall of the pot is removable; the glass in it is held by welts and a pair of "tongues" (Fig. 4—c).

Thus, in order to use the capillary method in studying the microbial situation in soils, in addition to capillary pedoscopes, which must be available in tens and even hundreds of samples, the following, rather simple devices are needed: steel punchers to insert the pedoscopes in the soil; a metallic stage for the preliminary examination of the pedoscopes with the living material under a microscope; thin, small slides and a metal frame for them to examine the capillary cells under the immersion lens under optimum illumination of the specimen; and also greenhouse pots with a removable side wall, if work with the pedoscopes is to be conducted under laboratory conditions.

The working method with the capillary pedoscopes is simple and is as follows:

Clean capillary cells are inserted in the holder and sterilized with dry heat. To coat the walls of the capillary channels with an agarized medium, corresponding substrate on diluted agar are prepared. Judging from our observations, the concentration of agar should not exceed 0.5% in the case of capillary cells with wide channels (Fig. 1—5), and 0.2% in the case of capillaries with narrow channels (Fig. 1—4). If the concentrations of agar are higher and it is not immediately drawn off with sterile cotton, transverse films of agar form in the channels on drying, which interfere with the movement of the soil solution along the capillary cells.

The agarized substrate is usually introduced into the capillary cells of pedoscopes with transversely arranged cells when they are in the holder. The end of a pipette with the liquified, sterile substrate is used to touch carefully one of the slanted ends of each capillary. The agar is drawn into the channels by capillary forces and after careful drying forms a film that firmly clings to the walls of the channels. The substrate which has penetrated into the holder and the outer surfaces of the cells must be removed by withdrawing the set of cells from the holder. The pedoscopes must be filled with the substrate under aseptic conditions in a box.

The capillary pedoscopes, filled with the sterile agarized medium, are placed in sterile Petri dishes into a drying cabinet where the lids are lifted slightly and they are dried at a temperature of 30°–45°C.

The pedoscopes thus treated may be placed into various horizons of the soil profile in the field.

Greenhouse pots may be filled with soil of any composition, or with a monolith taken directly from the soil profile. When kept in the laboratory, the monolith is periodically wetted with distilled water so that the microflora remains in an active

state. The use of such a "live monolith" is convenient for the comparative study of microbial associations of various soils under controlled temperature and moisture conditions.

Before inserting the capillary pedoscopes into the soil, the greenhouse pot is brought to the necessary moisture and the vessel is tilted or even placed on its wide, immovable wall. Then the wide front wall is carefully removed and the capillary pedoscopes are carefully inserted by means of the puncher into the selected places in the soil.

The capillary pedoscopes are kept in the soil from several days to several months, depending on the object of the investigation (see the article by Aristovskaya and Parinkina in this number of the journal). After the pedoscopes are withdrawn from the soil, the surfaces of the capillary cells are wiped with dry, clean cotton to remove the soil particles clinging to them.

It must be kept in mind that mobile bacteria, flagellata, protozoa, and certain representatives of the microfauna of the Metazoa are found in the capillary channels together with the attached microorganisms. The majority of them change beyond recognition on drying and it is not possible to determine whether they are capable of movement. This is why the microbial situation in the capillary cells of a pedoscope must be examined first in a living state, for which the special stage described earlier (Fig. 3-A) is useful.

For a more detailed study under immersion, the bacterial cells must be stained. To do this the capillary cells are dried, fixed over a flame burner or by some other means, and stain is introduced into the channels, such as a 5% solution of carbolic erythrosine, which is rapidly drawn in by capillary forces. After the stain is removed and the capillary preparation dried, the channels are filled with immersion oil or Canada balsam. To insure optimum illumination with an immersion lens, the capillary cells, removed from the holder, are mounted with Canada balsam on a thin slide, which is placed in the metal frame and on the microscope stage (Fig. 3-B).

Both the holders and the capillary cells of the pedoscope may be used repeatedly. To do this immersion oil and Canada balsam must be removed from the cells with xylene or another solvent, then they must be boiled in soapy water, kept in a chrome mixture, and washed of the latter by first boiling in tap water and then in distilled water. The holders are washed with a chrome mixture and then boiled in water. Then the capillary cells and holders are placed in a drying cabinet until all water is removed from the channels and their surfaces.

In developing the foregoing method we used garden soil placed in the greenhouse pots with a removable wall (Fig. 4) for tests. In testing the method we became convinced that when microbial growths develop in the capillary spaces of the pedoscopes, inserted into comparatively moist soil, it is imperative that the glass surface be coated with an agarized substrate, as it is recommended by Rybalkina and Kononenko (8, 9) for growth glasses. But the

concentration of agar must be several times lower. In our experiments with garden soil, micro-growths were more abundant in pedoscopes coated with various agarized substrates (water, mannite, peptone) than in capillary cells without a coating.¹

The main advantages of the capillary pedoscope, in our opinion, are the following: the micro-growths developing in the channels are well protected from mechanical damage, contamination with soil particles, and from evaporation, so that the weakly attached and mobile components of the microbial soil population are well preserved in them and the examination of the micro-growths in a live state under the microscope is facilitated.

From the optical point of view the capillary samples are in no way inferior to those on slides. The limited width of the channels of the pedoscope cells facilitates repeated observation of subjects found in the channels. The way the microorganisms attach themselves to the substrate can be observed on the vertical walls of the channels.

The technique of manufacturing capillary pedoscopes, developed in our laboratory, is simple.

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¹ At the present time capillary pedoscopes are used in the microbiology laboratory of the Central Soil Science Museum, Academy of Sciences, USSR. The first results of the application of this method to soils of the isthmus of Kareliya are described by T. V. Aristovskaya and O. M. Parinkina in an article in this issue.

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USE OF SPECTRAL ANALYSIS FOR THE STUDY OF SOIL EXTRACTS AND SOLUTIONS

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The development of agricultural science and practice promoted the introduction into agricultural chemistry and plant physiology of the most modern instrumental methods of investigation, including the method of emission spectral analysis. In recent years methods of determining sodium, potassium, and calcium in soil extracts, based on the photometry of the emissions of these elements in a flame (5, 9, 12), have been used widely in the laboratory. A number of works have been published on the spectral analysis of soils (2, 4, 10, 16). In spite of this, the introduction of photographic methods of emission spectral analysis into mass agricultural chemical investigations is not adequate.

The methods of spectral analysis of liquids, described in the literature (1, 4, 6, 7, 11), have a common serious disadvantage and therefore have not found wide application in agricultural chemical analysis.

As a result of our experiments, a new, rapid method of spectral analysis of soil extracts and solutions has been proposed and introduced into practice. This method consists of the following. The soil extract to be analyzed is changed into a highly disperse aerosol by means of a glass atomizer. The aerosol is sprayed through a nozzle into a discharge plasma where the spectra

of the elements contained in the aerosol appear.¹ The spectra of the emissions are photographed on a spectrograph.

The arrangement of the device for the spectral analysis of soil extracts and solutions by our method is shown in Figure 1. Compressed air from a cylinder, or compressor, is supplied to nozzle 2 of atomizer 3 through a small angular faucet 1. The air pressure at the inlet is measured by a manometer 4. Under the effect of the jet of air, issuing out of the inlet tube of the atomizer, the liquid under study is sucked from dish 5 into capillary tube 6, and is atomized into a highly disperse aerosol. The latter enters the consecutively connected drop collector-separator 7 and 8. In doing this, the aerosol jet sharply changes direction and speed three times, as a result of which large drops separate and drain into the lower part of the atomizer and the drop collector. The liquid is removed from the atomizer and separator by a rubber tube with

¹Earlier A. K. Rusanov (3) used the method of discharging aerosol into an arc flame to study the temperature conditions of excitation during the spectral analysis of powder-like substances in ore (minerals, slag, etc.).

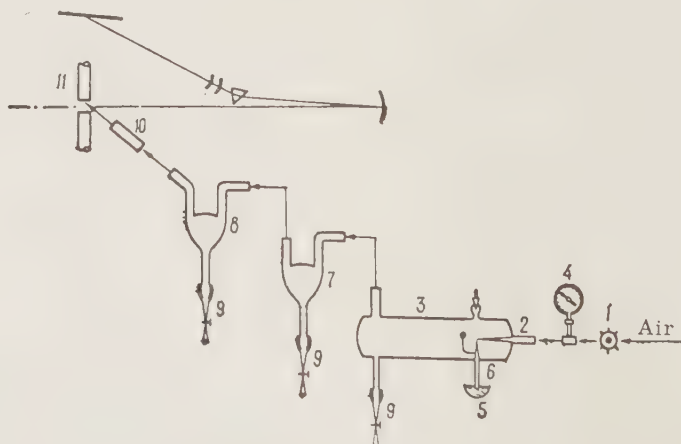


Fig. 1. - Arrangement of the device for the spectral analysis of soil extracts and solutions.

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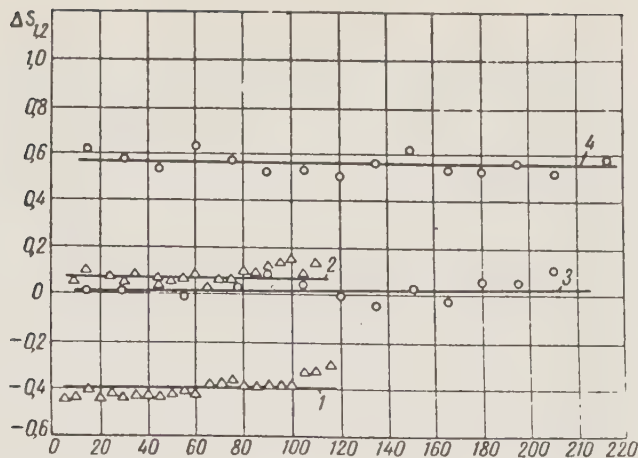


Fig. 2. - Dynamics of the change in ΔS values of the spectral lines

$\frac{\text{Ca } 3868,47 \text{ \AA}}{\text{Mo } 3902,26 \text{ \AA}}$ and $\frac{\text{Mg } 2795,53 \text{ \AA}}{\text{Mo } 2816,154 \text{ \AA}}$

with time during photography on a moving plate:

1,2 - ΔS of Mg and Ca lines during an exposure of 5 sec;
3,4 - same during an exposure of 15 sec.

Table 1

Relationship of the density of darkening (S) of the Mg 2795.53 $\text{\AA}$ line at the air pressure (P) to the inlet to the atomizer

P , atm	S_{Mg}
0,2	0,35
0,4	0,62
0,6	1,01
0,8	1,06
1,0	1,16

Note: Comma represents decimal point.

Table 2

Relationship of S of the Mg 2795.53 $\text{\AA}$ line and Ca 3179.53 $\text{\AA}$ to the diameter of the nozzle (D), ($P = 1 \text{ atm}$)

D , mm	S_{Mg}	S_{Ca}
2	1,08	0,56
	1,06	0,58
	1,07	0,57
3	1,28	0,64
	1,27	0,64
	1,28	0,66
4	0,85	0,53
	0,82	0,52
	0,83	0,53

Note: Comma represents decimal point.

clamps 9. The homogeneous aerosol is discharged through nozzle 10 into the space between electrodes during exposure.

The processes taking place in the arc when the aerosol is discharged into the analytical space results primarily in the instant evaporation of the very small crystals of the solid phase of the aerosol, thermal dislocation of the vapors of the substances, and excitation of atoms or ions.

The phenomenon of fractional evaporation, which sometimes interferes with the determination of elements by spectral analysis, does not occur here.

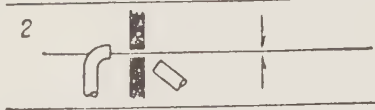
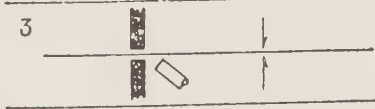
To find out whether all elements contained in the aerosol are excited simultaneously in the discharge plasma, we made the following experiments. We discharged into the analytical space an aerosol of calcium, magnesium, molybdenum, and sodium salt solutions of a

concentration of 0.003, 0.006, 1.02, and 1.0 g-eq/l, respectively. The spectra were photographed twice on a moving plate at exposures of 5 and 15 seconds. The data obtained attest to the ΔS values of the spectral lines of calcium, magnesium, and molybdenum shown in Figure 2, are practically constant when the aerosol is discharged into the discharge plasma.

It must be emphasized that in spite of insufficient knowledge of the process of aerosol excitation in an electrical discharge, the advantages of this method for mass analysis are doubtless. Let us note the following advantages: the possibility of accurately regulating and proportioning the amount of aerosol discharged into the

Table 3

Relationship of S of the Mg line to the position of the nozzle (P = 1 atm)

Position of the nozzle	$S_{Mg^{2802,69} \text{ \AA}}$	$S_{Mg^{2795,53} \text{ \AA}}$
	0,75	0,99
	0,71	1,00
	0,75	1,01
	0,72	1,00
	0,72	1,00
	0,69	0,98
	1,04	1,30
	1,05	1,34
	1,03	1,30

Note: Comma represents decimal point.

Table 4

Relationship of S of the Mg line to the space between the electrodes (d)

d, mm	$S_{Mg^{2802,69} \text{ \AA}}$	$S_{Mg^{2795,53} \text{ \AA}}$	d, mm	$S_{Mg^{2802,69} \text{ \AA}}$	$S_{Mg^{2795,53} \text{ \AA}}$
2	0,58	0,72	3,0	0,39	0,57
	0,54	0,72		0,39	0,59
	0,54	0,74		0,38	0,58
2,5	0,46	0,65	4	0,39	0,56
	0,43	0,61		0,38	0,58
	0,42	0,60		0,35	0,55

Note: Comma represents decimal point.

analytical space in unit time; the stability of the discharge under the effect of the air jet, a fact already noted by other authors (8, 14); the forced removal of the products of combustion from the analytical space; the simultaneous excitation of all elements present in the aerosol; the high sensitivity and reproducibility of the determinations; the simplicity and speed of the analytical procedure; and the simplicity of the preparation of standards.

As our experiments have shown, the sensitivity of the analysis depends on the air pressure at the inlet into the atomizer, the position in space and size of the aerosol nozzle, and also on the size of the space between the electrodes. The corresponding experimental data are given in Tables 1-4.

The data in Tables 1-4 show that the most

favorable parameters of the device are: an air pressure of 1.0 atm at the inlet to the atomizer (with the air capillary of the atomizer being 0.3-0.5 mm in diameter and the capillary for the liquid being 0.1-0.2 mm); a nozzle diameter of 3 mm; the position of the nozzle must correspond to the bisectrix of the right angle formed by the optical axis of the spectrograph and the vertical axis of the electrodes (with a distance between the mouth of the nozzle and the axis of the electrodes of 15 mm); and a space of 2 mm between the electrodes.

It must be noted that an increase in air pressure at the inlet into the atomizer to over 1 atm leads to the deformation of the aerosol jet and lowers the intensity of the lines measured. An air pressure of 1 atm at the inlet to the atomizer corresponds to a mercury column of 150 mm at the inlet to the capillary suction tube of the atomizer.

Attention is drawn to the dependence of the magnitude of darkening of the measured spectral lines on the position, direction, and method of delivery of the aerosol jet into the analytical space. When using position 1 (see Table 3), the possibility is not excluded that the emission will be absorbed by the spent aerosol jet, which forms an absorbing "cloud" between the electrode interspace and the first lens of the condenser system. In position 2, two aerosol jets are directed against each other, whereby a vortex forms in the center of the arc space and as a result only a small part of the aerosol produced in the atomizer enters the central region of the analytical space. The density of the darkening of the measured lines remains thereby at the same level as in position 1.²

²When this article was being prepared for the printer, an article by Shuravlev (3) appeared in the journal (Footnote continued on the next page)

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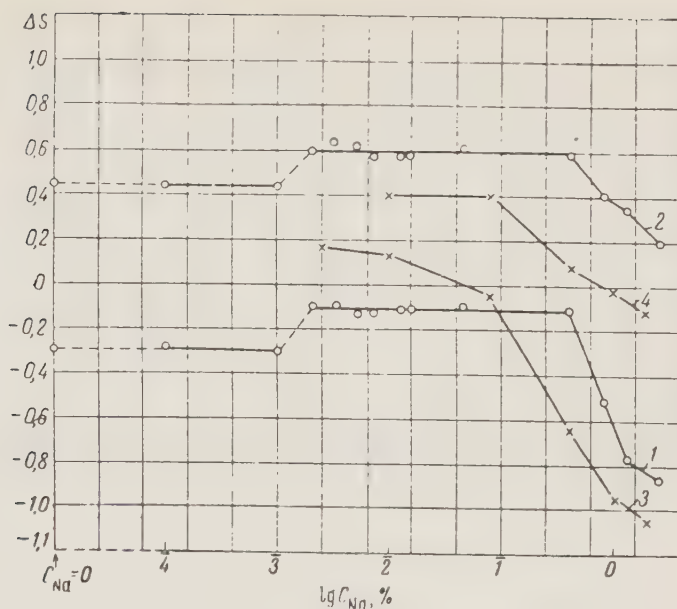


Fig. 3. - Relationship of ΔS values of the spectral lines

$$\frac{\text{Ca } 3179,33 \text{ \AA}}{\text{Mo } 3170,347 \text{ \AA}} \text{ and } \frac{\text{Mg } 2795,53 \text{ \AA}}{\text{Mo } 2816,154 \text{ \AA}}$$

to the sodium concentration:

1-2 - ΔS of Ca and Mg lines, the solutions of which are added into the slit in the form of an aerosol; 3-4 - same for the same solutions applied to the end of an electrode in the form of drops.

Table 5

Relationship of S and ΔS of the spectral lines of Ca, Mg, and Mo to the duration of the action of the electrical discharge and of the aerosol on the same pair of electrodes (exposure, 60 sec)

Duration of the action, sec.	$S_{\text{Mg } 2795,53 \text{ \AA}}$	$S_{\text{Mo } 2816,154 \text{ \AA}}$	$\Delta S_{\text{Mg-Mo}}$	$S_{\text{Ca } 3179,33 \text{ \AA}}$	$S_{\text{Mo } 3170,347 \text{ \AA}}$	$\Delta S_{\text{Ca-Mo}}$
60	0,35	0,15	+0,20	0,27	0,27	0
120	0,60	0,29	+0,31	0,39	0,46	-0,07
180	0,60	0,29	+0,31	0,40	0,48	-0,08
240	0,61	0,33	+0,28	0,43	0,54	-0,11
300	0,63	0,33	+0,30	0,42	0,51	-0,09

Note: Comma represents decimal point.

"Zavodskaya laboratoriya" in which the author proposes to stabilize the spark discharge by means of two aerosol jets, directed against each other in the space between the electrodes.

The best results are obtained in the third case. In position 3 the aerosol jet hits the end of the upper electrode. As a result, the duration of the "contact" between the aerosol and the electrical discharge, and the concentration of the substance studied in the analytical space considerably increase as compared to the foregoing cases.

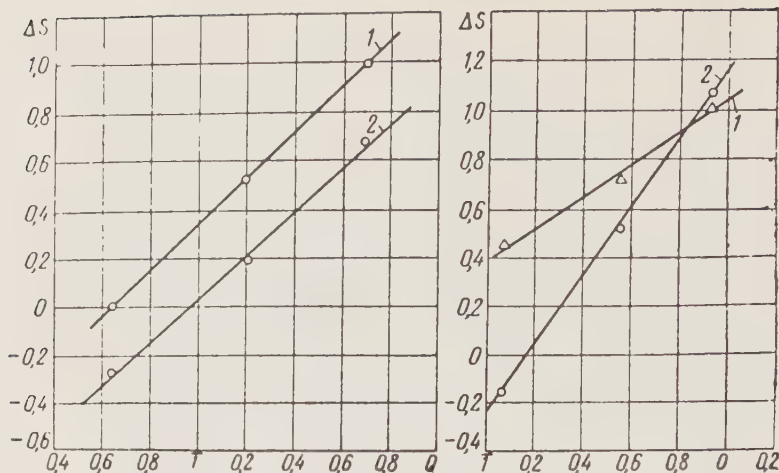


Fig. 4. - Calibrated graph for magnesium (a) and calcium (b) solutions:

1 - for water solutions $\text{Mg} \left(\frac{\text{Mg } 2795,53 \text{ \AA}}{\text{Mo } 2816,154 \text{ \AA}} \right)$
 and $\text{Ca} \left(\frac{\text{Ca } 3179,332 \text{ \AA}}{\text{Mo } 3170,347 \text{ \AA}} \right)$; 2 - for solutions $\text{Mg} \left(\frac{\text{Mg } 2795,53 \text{ \AA}}{\text{Mo } 2816,154 \text{ \AA}} \right)$ and
 $\text{Ca} \left(\frac{\text{Ca } 3933,666 \text{ \AA}}{\text{Mo } 3902,963 \text{ \AA}} \right)$ in 1-N NaCl.

Apparently, this explains the relative increase of the density of darkening of the lines measured, which is observed in position 3. In this position the arc "cloud" moves along the optical axis under the influence of the aerosol jet in such a manner that the electrodes diaphragm part of the stream of light emitted by the pre-electrode regions of the arc flame. The sensitivity does not decrease with this, because the highest intensity of the lines of neutral and ionized atoms of the substances contained in the aerosol is always observed in the central region of the arc flame (14).

Among the little known phenomena observed in the arc when the aerosol is discharged into the analytical space are the mechanics of the entry of the substance into the discharge plasma.

We studied the dynamics of the changes of the S and ΔS values of the spectral lines of calcium, magnesium, and the internal standard—molybdenum—in relation to the duration of the action of the electrical discharge and of the aerosol on the same pair of electrodes.

The concentration of calcium, magnesium, and molybdenum in the solutions studied was 5×10^{-4} , 1.8×10^{-4} , and 4.5×10^{-4} g-eq/l, respectively. Some of the results of the investigations are given in Table 5.

The data in Table 5 show that during the analysis of dilute solutions, the intensity of the spectral lines of all three elements mentioned does not reach its maximum during the first 60 seconds of the burning of the arc. However,

Table 6

Composition of standard solutions

Element	Concentration of the element in g-eq/l, standard solutions intended for analysis					
	Water extracts			Salt extracts		
Ca	0,0013	0,00049	0,00015	0,0017	0,0007	0,0003
Mg	0,00004	0,00025	0,0010	0,0010	0,0003	0,0001
Na	0,0044	0,0044	0,0044	1,0	1,0	1,0
K	0,0026	0,0026	0,0026	0,0026	0,0026	0,0026
Mo	0,034	0,034	0,034	0,034	0,034	0,034

Note: Comma represents decimal point.

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Table 7

Results of comparative determinations of calcium and magnesium in soil samples
(meq 100 g of soil)

Soil	Ca content found by the method				Mg content found by the method			
	spectral	complexometric	deviation		spectral	complexometric	deviation	
			meq	%			meq	%
Water extracts								
Solonchak-like soil	0,178	0,169	+0,009	5,3	0,376	0,400	-0,024	6
Solonchak-like soil	0,245	0,266	-0,021	7,9	0,162	0,141	+0,019	13,5
Solonchak-like soil	0,355	0,314	+0,041	13	0,072	0,079	-0,007	8,9
Solonchak-like soil	0,112	0,097	+0,005	5,1	0,046	0,051	-0,005	9,8
Solonchak-like soil	0,170	0,167	+0,003	1,8	1,67	2,2	-0,053	2,4
Salt extracts								
Slightly humic, podzolized chernozem	10,70	9,75	+0,95	9,7	1,65	1,95	-0,30	15,4
"	3,54	3,95	-0,41	10,4	1,16	1,31	-0,15	11,5
Dark-gray podzolized soil	11,18	11,30	-0,12	1,0	1,21	1,21	—	—
"	11,98	11,50	+0,48	4,2	1,15	1,02	+0,13	12,7
"	6,14	6,7	-0,56	8,4	1,16	1,03	+0,13	12,6
Gray podzolized soil	6,84	7,3	-0,46	6,3	1,08	1,05	+0,03	2,8
Slightly humic, deep chernozem	16,19	15,7	+0,49	3,1	0,91	0,81	+0,10	12,4
"	5,24	4,53	+0,71	15,7	0,69	0,78	-0,09	11,5
"	5,76	5,72	+0,04	0,7	1,55	1,9	-0,35	18,4
Slightly humic, podzolized chernozem	12,01	12,9	-0,089	0,7	0,54	0,55	-0,01	1,8
Sod slightly podzolic soil	0,72	0,76	-0,04	5,3	0,52	0,59	-0,07	11,9

Note: Comma represents decimal point.

after the next 60 seconds the values of S and ΔS reach their maximum and do not change during the next three 60-second exposures. At the same time, when analyzing more concentrated solutions (Fig. 2), the maximum density of darkening of the lines studied is practically reached 10-15 seconds after the arc is switched on. A critical evaluation of these phenomena, as well as the results of the selection of a rational position for the nozzle (Table 3) allows one to make an assumption on the mechanics of the introduction of elements into the discharge plasma during the discharge of the aerosol into the analytical space. Apparently the main and direct "supplier" of the substance subjected to excitation in the electrical discharge is not so much the aerosol which is discharged into the analytical space, but an adsorption film which forms at the end of an electrode (probably the upper) at the moment when the aerosol jet touches the hot surface of the electrode. The following phenomenon may occur during the analysis of dilute solutions. During the first moment after the device is put into operation, the loss of dry substance by the adsorption film exceeds the supply of dry substance by the aerosol to the surface of the electrode and therefore S is small. Later, as the absolute amount of

aerosol which has passed the analytical space increases, a state of equilibrium sets in during which the loss of dry substance by the adsorption film is fully compensated by the supply of new portions of dry substance from the aerosol jet. With this, S reaches its maximum and remains constant. The speed with which equilibrium is reached depends primarily on the concentration of elements in the aerosol. The higher the concentration of elements, the faster do processes of destruction and restoration of the adsorption film at the end of an electrode (or electrodes) equilibrate, and the sooner S reaches its maximum. The formation of the adsorption film greatly depends on the shape and position of the nozzle. As we have already seen (Table 3), position 3 gives the best results.

Data in Table 5 also show that the duration of the preliminary combustion when both electrodes are sprayed simultaneously with the aerosol may exceed 60 seconds, and that the same pair of electrodes may be used without cleaning to obtain three or four spectrograms of the same soil extract or solution.

There is information in the literature on the disturbing effect of sodium and potassium,

contained in the sample, on the excitation of the emission of other elements (1). In relation to this it proved very important to study the influence of potassium and, especially, sodium on the intensity of spectral lines of calcium and magnesium contained in water and especially in salt extracts (using 1-N sodium chloride as a solvent).

The data obtained on the influence of sodium on the relative intensity of the spectral lines of calcium, magnesium, and the internal standard—molybdenum—are given in Figure 3.

As may be seen from the data, the presence of $0.1 \times 10^{-3}\%$ sodium in the solutions investigated has practically no effect on ΔS . Within a range of sodium concentrations from 1×10^{-3} to $2 \times 10^{-3}\%$, the relative intensity of calcium and magnesium lines increases somewhat and then remains constant until the concentration of the alkaline element reaches $4 \times 10^{-1}\%$. A further increase in the concentration of sodium is accompanied by a decrease of ΔS . From this it follows that the content of the alkali element in standard solutions must correspond to the content of the same element in the solutions studied in the case when its concentration exceeds $1 \times 10^{-3}\%$.

We obtained analogous data when we studied the effect of potassium on the intensity of the lines of the foregoing elements.

Figure 3 (curves 3, 4) also gives the results obtained by us during a study of the excitation of the spectrum of a solution applied to the end face of a carbon electrode in the form of a drop. With this method the disturbing influence of the alkali element begins to manifest itself at much smaller concentrations than in the foregoing case.

We found that ammonium chloride has no effect on the relative intensity of the spectral lines of calcium and magnesium. Therefore there is no need to add this salt to the standard solutions when analyzing soil extracts obtained with ammonium chloride.

Our method of spectral analysis of soil extracts and solutions has been introduced into the practice of mass soil investigations by our collaborators at the Ukrainian Agricultural Scientific-Research Institute. The method is used primarily for determining the calcium and magnesium content in water extracts and adsorbed calcium and magnesium extracted from samples of soil with an 1-N solution of sodium chloride.

The spectra are photographed on an ISP-22 spectrograph provided with a DG-2 generator, which is connected according to the II-III scheme (arc); the current is 2 amp, the width of the spectrograph slit is 30μ ; the duration of the preliminary combustion of the electrode, as well as that of the exposure proper is 60 seconds; the dimensions of the carbon electrodes are 6×15 mm; and the photographic plates are spectral plates (type I and III).

The spectral analysis is performed by the method of three standards. Molybdenum in the form of heptamolybdenum ammonia is used as the internal standard. The content of this salt

in standard solutions corresponds exactly to the amount of molybdenum added before analysis to the solutions studied.

Data on the composition of standard solutions used during the analysis of water extracts from soil, as well as that of salt extracts are given in Table 6.

For the analysis of water extracts from soils, the following pairs of analytical lines were selected:

$$\frac{\text{Mg } 2795,53 \text{ \AA}}{\text{Mo } 2816,154 \text{ \AA}} \text{ and } \frac{\text{Ca } 3179,332 \text{ \AA}}{\text{Mo } 3170,347 \text{ \AA}}.$$

When determining calcium in salt extracts from soil one can use the more sensitive lines Ca 3933.666 Å or 3968.468 Å because of the weakening of the background near cyanogen under the influence of sodium chloride. The absolute sensitivity of the determination of Mg is $1 \times 10^{-5}\%$ and that of Ca, $1 \times 10^{-6}\%$.

Approximate calibrated graphs for the determination of calcium and magnesium are given in Figure 4.

The slope of the calibrated graph for the analysis of salt extracts for calcium (Fig. 4, a, 2) is considerably greater than in the case of water extracts.

The relative error in the determination of calcium during the analysis of water and salt extracts from soils is 5.1% and 3.1%, and for magnesium it is 3.8% and 3.0%, respectively. The higher accuracy in the analysis of salt extracts is probably due to the fact that a more sensitive calcium line is used, and to the stabilizing effect of sodium on the discharge (3).

Certain results of comparative tests of the same extracts made by our method of spectral analysis and the method of photoelectric titration using complexometry (15), are given in Table 7. These data show that the absolute deviation between the results of the analyses does not exceed 1 meq for calcium and 0.35 meq for magnesium per 100 g of soil. The relative deviation during the determination of calcium and magnesium varies from 0.7-10% and 1.8-13%, respectively.

The data obtained allow us to recommend that our quick method of spectral analysis of soil extracts be introduced into mass agricultural chemical investigations.

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USE OF ION EXCHANGE RESINS FOR STUDYING HUMUS SUBSTANCES

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Many types of cations and anionites are presently being put into production on a wide scale in a number of countries, while the process of ion exchange sorbents is being used in chemistry, biology, and medicine. Many investigators are using ion exchange resins in studying humus substances (1, 2, 7). We should point out that despite the broad application of ion exchange resins, the theory of the problem and the basis for empirical facts have been worked out but slightly, especially for the sorption process of organic compounds. A discussion of work on this problem is found in the monographic volumes of Samuelson (10), Grissbach (8), and in other collections (4, 5, 6).

Ion exchange resins are high-molecular amorphous compounds, insoluble in water; their macromolecules have a reticular or random, confused (irregular) structure. They contain single-type or varied-type ionogenic groups, capable of ion exchange reactions. In the cation exchange resins (the cationites or cation-exchanging substances) the ionogenic groups are acidic—the hydrogen ion of these groups is exchanged for the cation of the solution. Most often the resin cationites used are the SO_3H and COOH group. In the anion-exchange resins (the anionites) the ion exchange groups possess basic properties, the hydroxyl groups in them are exchanged for the anions of the solution. The reactions of the ion exchange on the resins are always heterogeneous, because they are developed on the outer boundary of the sorbent-solution and within the nucleus. The possibility of the latter development is determined by the extent of permeability (penetrability) of the inner structure for the ions of the solution. The reaction rate of ion exchange for the resins is determined basically by the diffusion rate of the absorbable ion within the nucleus of the ionite toward the point of exchange and essentially changes as a function of the size of the particle. This enables us to use the percolation method for ion exchange. A series of secondary processes usually occurs along with the ion exchange processes: molecule absorption, physical adsorption, ion reduction, which we must take into account when selecting the sorbent and work conditions. Ion sorption of organic compounds is determined, first of all, by the extent of their ionization and molecule size because large size ions of organic compounds cannot penetrate deep within the particle of the ionite which has a low intramacromolecular porosity. The degree of

ion sorptability of organic compounds is determined to a large extent by the measure of the swelling capacity of the ionite. The higher the measure of swelling capacity, the more large size ions of organic compounds can be sorbed. In addition, a small measure of large size ion absorption can be used for purifying organic compound solutions of small inorganic cations and anions.

In our experiments we used a high acid cationite KPS-200 (active groups SO_3H , adsorption capacity 4.4 meq per g), and a strong base anionite L = 150 (absorption capacity 10 meq per g) of German manufacture. The ion exchange resins were prepared for analysis, according to instructions of Samuelson (10)—the H-cationite, the OH-anionite, particle diameter 0.5-0.25 mm, height of column 40-60 cm, diameter of column 2 cm.¹ Percolation rate of the solution was 2-4 ml/cm² per minute.

The humus substances used were humic and fulvic acids of the humus horizon of chernozem and podzol soil, separated by ordinary means, and water soluble humus substances derived from 6 to 12 month-old decomposition products of clover and timothy. Concentration of solutions did not exceed 500 mg of C per one liter. Experiments on percolation of humus substances through a cationite have shown that the bulk of humic and fulvic acids passes through the cationite with only a small part of these acids absorbed by it (Fig. 1, A). Absorption takes place during percolation of a new portion of the solution; repeated percolation of the solution, passed through the cationite, does not result in additional absorption (Table 1).

We might assume, therefore, that there is in the solutions of humic and fulvic acids a small number of positively charged organic ions, which are the products of nitrogeous decomposition. The solution of humus substances after percolation through the cationite has an acid reaction (pH = 3.5 - 4). We ought to point out that, in some cases, when there is a high percentage of electrolytes through the H-cationite, precipitation of humic acids in the mass of cationite occurs

¹One hundred ml capacity burettes with a glass stopcock are used for preparing the columns.

ION EXCHANGE RESINS

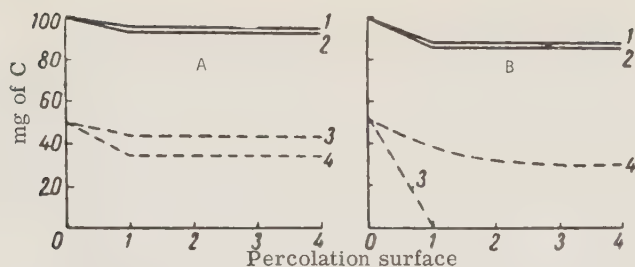


Fig. 1.— Amount of C of humic and fulvic acids after percolation through the cationite (A); amount C of humic and fulvic acids after percolation through anionite (B).

1 - humic acids; 2 - fulvic acids; 1-3 - chernozem;
2-4 - podzolic soil.

because in the percolation process, owing to the anions of the solution (SO_4 , Cl^-) there are formed free mineral acids, which precipitate the humic acid. Precipitate is easily removed from the column by distilled water.

We have worked out a method for separating humic and fulvic acids by use of the cationite,

and we have also worked out a means for deriving the sol of humic acids or of a humate of Na of required pH value, by having used the cationite as a coagulator. For this purpose we should put 30-40 g of cationite into a cellophane bag and lower it into a solution of humus substances. The solution will gradually be acidified as the result of the exchange reaction between the H of the

Table 1

Adsorption of Na humate of chernozem (pH = 6.8) by a cationite
(in 20 ml initial solution of 3.96 mg of C)

Solution	Mg of C found in 20 ml solution after percolation						
	Number of times percolation repeated						
	1	2	3	4	5	6	7
First portion	3,62	3,21	3,51	3,57	3,49	3,55	3,56
Second portion	3,57	3,34	3,56	3,58	3,57	3,53	3,52
Third portion	3,62	3,52	3,61	3,54	3,56	3,61	3,58

Note: Comma represents decimal point.

Table 2

Adsorption of Na humate of chernozem (pH = 6.8) by an anionite
(in 20 ml initial solution of 5.5 mg of C)

Solution	Mg of C found in 20 ml solution after percolation				
	Number of times percolation repeated				
	1	2	3	4	5
First portion	4,85	4,81	4,85	4,87	4,86
Second portion	4,83	4,85	4,82	4,84	4,85
Third portion	4,86	4,84	4,85	4,86	4,86

Note: Comma represents decimal point.

Table 3

Amount of humic acids and their ash content

Solutions of humus substances	Ash content, % of dry matter	Amount of humic acids, mg found		Ash content of humic acids after percolation through anionite + cationite, % of dry matter
		By precipitation in 0.1n H_2SO_4	by percolation through anionite + cationite	
Water extract from 12 month old decomposition products of:				
clover	48,5	76,6	74,2	2,4
clover	41,4	74,5	72,1	2,5
timothy	50,3	66,7	82,4	1,9
0.1n NaOH extract from:				
Chernozem	—	90,6	87,6	—
Chernozem	—	96,0	92,0	—
podzolic soil	—	82,6	86,9	—
podzolic soil	—	75,3	80,1	—

Note: Comma represents decimal point.

cationite and the cations of the humus substances. When the pH value is 3.0 there will be total precipitation of the humic acids. They may be filtered off, peptized by water or dissolved in weak alkali or sodium bicarbonate (0.2 n) solutions and used for later analyses. To derive the sol of humic acids or of the humate of Na having a required pH value we need only to place the cellophane bag and cationite into a humate solution and to observe systematically the change in the pH of the solution. After the solution has reached the required pH, the bag and cationite are removed and the solution used immediately.

Studying the extent of adsorption of same solutions of humus substances by an anionite has shown that the bulk of humic acids is not adsorbed by the anionite, although a small quantity of these humic acids is retained in the column (Fig. 1, B). Repeated percolation does not increase the amount of humic acids which can be adsorbed (Table 2).

The failure to adsorb a large part of the humic acids and humates which have a negative charge in the solution may be explained only by the large quantity of their organic anions, which do not penetrate within the particle of the anionite because of the small internal porosity of the organic anions.

We observe a different picture in the percolation of fulvic acid solutions through a column of anionite (Fig. 1, B). The fulvic acids derived from chernozem and from a decomposed mass of clover are totally adsorbed by the anionite, whereas the fulvic acids obtained from podzolic soil and from the products of timothy humification are only 40%-60% adsorbed by the anionite. These data prove the heterogeneity of various fulvic acids. Obviously, the fulvic acids of chernozem and of a humified mass of clover are

more dispersed and are the products of a more profound stage of humification than the fulvic acids of podzolic soil and of a decomposed mass of timothy. Kononova (3), and Hock (9) have shown the heterogeneous nature of the fulvic acids of chernozem and podzolic soil. Use of the anionite confirms the accuracy of their judgments. We should point out that the mineral anions— SO_4^{--} , Cl^- , HCO_3^- , NO_3^- , PO_4^- are totally adsorbed by anionite, and the solutions of humus substances are released of these anions in the percolation process.

Our research has shown that it is expedient to use cationite and anionite in one column for the fractionization and purification of solutions of humus substances, wherein the cationite is set into the lower part of the column, and the anionite into the upper. In this case the anions and fulvic acids are first adsorbed from the solution, while during subsequent percolation through the cationite the humic acids are purified of cations. Having determined the percentage of C in the solution before and after percolation through the column, we then obtain the C of humic acids and fulvic acids. To illustrate this, we see in Table 3 the amount of humic acids of various origin found by this method and by precipitation of humic acids in 0.1 n solution of H_2SO_4 .

The amount of humic acids capable of being precipitated by acid from the water extracts of a decomposed mass of clover and from the alkali extracts of chernozem is, for all practical purposes, the same as the amount of humic acids obtained during percolation through a column of anionite and cationite. The somewhat higher yield of humic acids from podzolic soil and from the decomposition products of timothy is explained by the fact that a part of the fulvic acids is not adsorbed by anionite and passes into the filtrate. This part of the fulvic acids probably approaches the humic acids in properties.

Conclusions

1. Cation exchange resins may be used for purifying humus substances of cations, for separating humic and fulvic acids, and for obtaining humate solutions of Na having a required pH value.
2. Anion-exchange resins can be recommended for purifying solutions of humic acids and humates of mineral anions and for studying the nature of fulvic acids.
3. A method has been suggested to use the cationite and anionite in one column for separating humic acids of low ash content from water and alkali solutions of humus substances.

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AN IMPROVED PIPETTE FOR SAMPLING SOIL SUSPENSION

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A pipette proposed for sampling soil suspensions during particle-size analysis was constructed in a glass blower workshop. Results of 210 pairs of parallel determinations made using our pipette and A. M. Vasil'yev's pipette were in complete agreement, providing a suction apparatus (aspirator) was used.

We must be sure to assemble a pipette by using a suction apparatus which guarantees a strictly fixed suction rate. This pipette has, in all, one working stopcock, because the stopcock on the vessel is opened once a day or once every few days and can be replaced by a pinchcock on a rubber tubing.

The main stopcock of the pipette has three tubes arranged at 120° angles. A pipette is fixed to the left tuber (Fig. 1, A). A vessel is fixed to the symmetrical tube while a hose leading from a vessel containing distilled wash water is placed on the upper tube. The aspirator hose is connected to a branch piece which is fixed to the upper part of the vessel. An ordinary stopcock which can be replaced by a Mohr or Hoffmann pinchcock is fixed to the lower part of the vessel.

The capacity of the vessel is approximately 14 ml; this permits us to remove excess suspension from it during accumulation of a large amount of suspension and not after each sampling.

The main stopcock of the pipette (Fig. 1, B) has a 15-20 mm diameter in the flat tube. In the stopcock is a channel uniting the tubes in pairs and an additional channel at the end of the stopcock connected to the atmosphere, separating between the ends of the first channel. The tail end of the stopcock projects 10-15 mm beyond this casing and has a catch on which the hose used for blowing out the pipette is secured.

The handle of the stopcock is constructed in the shape of a pointer, because it is difficult to make accurate turns of 30-60 and 120 degrees.

On the casing of the stopcock an edge should be constructed with holes for securing the scale (Fig. 1, C). From a diagram of the scale we see that to sample a suspension we will need to shift the stopcock four times, wherein turns are made in succession with the hour hand. Frequently after washing, water remains in the pipette. This water should be blown out using an ordinary bulb with an extra opening in the spherical part, by stopping up the hole with the finger. The position of the stopcock during blow-out is the same as during discharge.

From Figure 1, D we see that we must calibrate the pipette by taking into account the passage of the stopcock. If the pipette were not commercially made we could then use a stopcock device taken from the Vyurys-Shtroley apparatus; we would have to drill into this stopcock a face opening with a bevel in the axial plane of the branch pieces; the vessel can be made out of the lower part of the burette while side openings can be made in the ordinary pipette. The volume of the pipette in this case is not exactly known. We should measure the volume by one or another means and introduce the corresponding correction into the computation formula.

A distinctive feature of the pipette is the fact that it is easy to work with. The analyst deals with one stopcock. The pipette is lowered when the stopcock is at zero, when the opening of the pipette is shut. After lowering the pipette into the suspension, the stopcock is turned to the "fill" position after which the aspirator is started. When the pipette is filled with an obvious surplus, and this happens if the suspension passes in the channel of the stopcock and begins to enter the tube of the vessel, the stopcock is turned to the "measured sample" position and the suction apparatus turned off. Then the pipette is raised, emptied, washed, and blown out. The suspension which has been left in the passage of the small tube of the vessel does not interfere with the next sampling.

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Figure 1 on following page

SOIL SUSPENSION PIPETTE

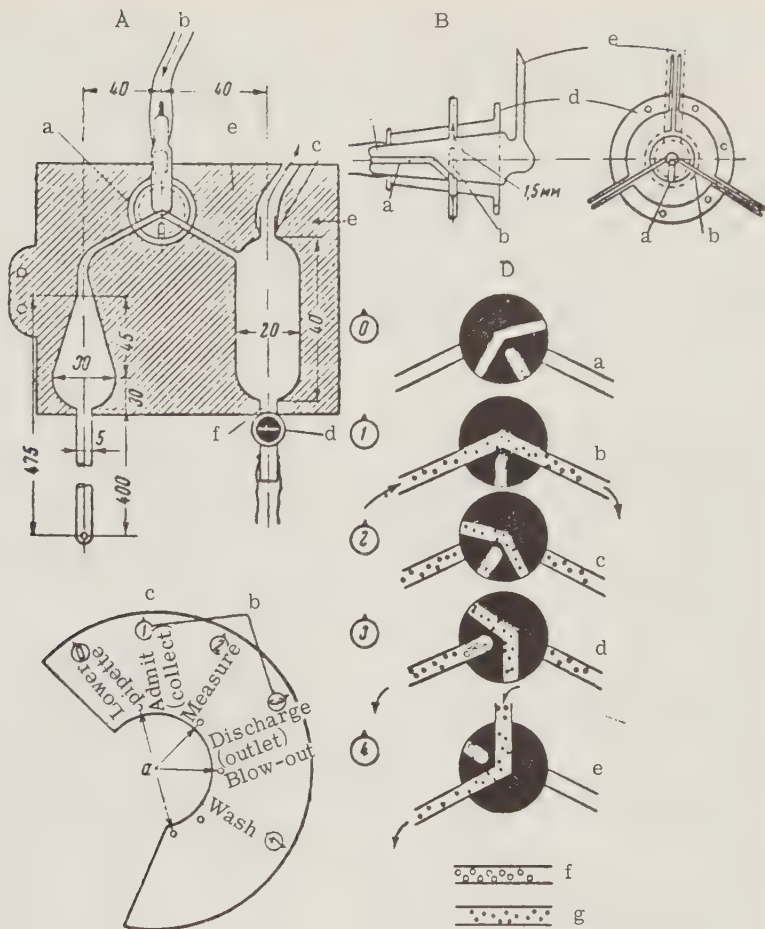


Fig. 1. - Overall view of pipette (A): a - main stopcock of pipette; b - tube to distilled wash water; c - branch piece of vessel for aspirator hose; d - ordinary stopcock of vessel; e - wooden panel with slots for projecting parts of pipette making it rigid and able to be secured to support clamp; f - branch piece of vessel for removing suspension surplus accumulated. Construction of main stopcock of pipette (B): a - air passage, 1,5 mm diameter; b - passage joining tubes in pairs, 1,5 mm diameter; c - catch for blow-out hose; d - edge for securing scale; e - stopcock handle in shape of pointer. Exterior view of pipette scale (C): a - holes for securing to edge of main stopcock; b - positions marked after securing scale on stopcock, conforming to each operation. Operational diagram of main stopcock of pipette (D): (pipette at left; at right, the vessel joined to suction apparatus and discharge). a - lowering pipette; b - admitting or collecting suspension; c - measuring suspension; d - discharging suspension sample; e - washing pipette; f - air; g - water and suspension.

A SPANISH TEXTBOOK ENTITLED—SOIL SCIENCE, (ANNOTATION AND NEW DATA ON SOILS OF SPAIN)

M. I. GERASIMOVA

The popular textbook "Soil Science," "Edafologia" written by Jose M. Albareda and Angel O. de Castro is the first in Spanish literature on the subject of soil science. It is designed for students of the pharmaceuticals department. This book is the second edition published in 1955 wherein chapters on humus and clay minerals have been enlarged, a description of new soil groups included, and a chapter on soil utilization added.

The textbook contains 356 pages and consists of three parts: 1) formation and properties of soils; 2) soil groups; and 3) their agricultural utilization.

Appended is a bibliography containing 57 references including works by Russian soil scientists K. K. Gedroyts and K. D. Glinka.

The textbook has very little original material on the description of the general soil properties. Therefore, we shall dwell only on those sections dealing with soils little known in the USSR, namely, soils on carbonate rocks, rankers, and soils of tropic and subtropic countries.

Soils on carbonate rocks. From V. Kubi-
ena's classification we have the following groups: rendzinas, red and brown carbonate clay loams, terra rossa and terra fusca.

Rendzinas. There exist several stages in Rendzina development and, correspondingly, several Rendzina subgroups. First, the carbonate parent material formation is inhabited by different species of lichens (Verrucaria calciseda, Lecanora crassa), then by moss Grimmia orbicularis and, finally, by higher plants, usually meadow crops (Globularia cordifolia). Kubi-
ena suggests considering as the origin of soil formation parent material from the moment Grimmia orbicularis settles on it. He calls the soil in this stage protorendzina. The humus horizon is thin and consists of plant residue and the excrement of certain animals (with the latter better humified).

Subsequent succession of vegetation and appearance of Globularia and Sesleria varia con-

form to the formation of "soft" rendzinas (mulliforme). We find these soils under grass meadows, heather moorlands, and pine forests. They are widespread in central and northern Europe. The humus of "soft" rendzina has the same composition as protorendzina but the degree of humification is greater, although humus compounds containing clay substances are missing. There is an A_{Ca} carbonate horizon.

The thickness of profile gradually increases; decomposition becomes more intensive; earthworms move in and form a "soft" humus already associated with the mineral part of the soil. The thickness of the humus layer increases to 15-35 cm. Next comes the A_{Ca} horizon becoming parent material, usually marl. Kubi-
ena calls this subgroup mullrendzina and regards chernozem as analogous. The mullrendzinas are soils of forests and Central European meadows which have shed their leaves.

All species of rendzinas have a neutral or slightly alkaline pH; the carbonates are found throughout the entire profile. No new formation of secondary minerals takes place in the Rendzinas; they simply undergo modification. The sesquioxides coagulate immediately after liberation; silica is slightly leached downwards.

As rendzinas are further developed, calcium carbonate is gradually leached and the soil becomes brown as a result of the appearance of ferric oxides. This Rendzina in the degradation stage is called a brown rendzina (rendsina parda).

Clay loams on limestone. These soils may be assigned to the over-mature group; the calcium carbonate has been entirely leached from them; secondary clays have been formed, and iron is found in the form of incrustations and concretions. In texture and forms of iron content these soils resemble tropical red and brown clay loams.

Terra fusca is a brown clay loam having the following profile:

1. A humus horizon, dirty gray, very thin, made up of mull-like humus and abundantly inhabited by earthworms.
2. A B horizon, very compact, without pores, and plastic. Calcium carbonate is absent; a synthesis of clay minerals and liberation of clay from

¹ Soil Science, 1955, Madrid.

the bedrock formation take place. Micas and halloysite form a large part of the clay. The plasticity of the horizon is explained by the presence of a colloidal silicon dioxide which peptizes the iron. Consequently, there are formed around the soil aggregates thin films of ferric hydroxides. They are formed over a long period of time and in a favorable climate during variable moisture. Owing to the presence of silicic acid and ferric hydroxides under these conditions, the B horizon is of yellowish-brown color slightly dependent upon the degree of moisture. We also find red-brown incrustations of iron.

3. A carbonate parent material, usually very dry. Between the B and C horizons it may be transitory, carbonate, formed by leaching of carbonates from the profile.

The brown-carbonate clay loam is formed in countries having a warm climate and moist summer, and usually under forests. We find them in the northern and eastern parts of the Alps on limestone outcrops, also in Hungary and in the Balkans. A stony *terra fusca* (*terrosa*) is a variety of *terra fusca*. It has coarser physical properties, is widespread in dry regions, often together with red-carbonate clay loams. Another variety of *terra fusca* is distinguished by the presence of a whitish horizon beneath the humus horizon, which is explained by the leaching of iron when peptized by silicon dioxide.

Red clay loams on limestone (*terra rosa*) have much in common with the brown clay loams. The soils are thoroughly leached, deficient in bases, plastic, compact, and strongly eroded. In contrast to *terra fusca*, *terra rossa* has a red B horizon with numerous and very stable concretions and incrustations of iron. The combination of a dry and hot summer and a cool and moist winter is conducive to this formation. During intense leaching, the iron peptized by silicon dioxide is leached downwards; a stony *terra rossa* is formed. Conditions conducive to the formation of leached red clay loams, according to E. Blanck, are: 1) a pure carbonate rock. We never encounter *terra rossa* on marl as opposed to *terra fusca*; 2) high temperatures of soil surface and extreme dry climate. During capillary rise of the soil solution the cations enter it and the soil reaction is maintained as neutral or weakly alkaline. *Terra fusca* has a weakly acid or neutral reaction; 3) rapid decomposition of humus during its negligible intake into the soil; and 4) a surface denudation.

The areas where *terra rossa* are widespread are: Austria, Dalmatia, Southern Italy, Greece, Sicily, Crete, and Spain.

We usually find brown carbonate clay loams alongside soils of the *rendzina* group; thus, Kubiena has distinguished the following soil subgroup (by increase in the content of the clay fraction, humus, and by decrease in the amount of carbonates): the protorendzina—the mulliforme rendzina—the mullrendzina—the brown rendzina—the brown carbonate clay loam.

Terra fusca is the final stage and under central European conditions has not undergone subsequent development. In Mediterranean climate *terra fusca* becomes *terra rossa*. Proof of this

is the fact that these soils are often found together. Sometimes the *rendzinas* may become *terra rossa* without going through the intermediate *terra fusca* stage.

In interchanging these soils we note, besides a latitudinal, a vertical zonality. *Terra rossa*, being slightly eroded, is found on comparatively level strips and on peaks of mountains but not higher than 2,000 meters. Below this we find *terra fusca* and further down *rendzinas*.

Ranker. The ranker usually is found on acidic rocks and somewhat resembles the *rendzinas*, but in contrast to the *rendzina*, it cannot remain for long in the ranker stage but becomes brown forest podzols or peat depending upon the conditions.

We rarely find the ranker in Central Europe. The ranker was first described by Kh. Pall'man in the Swiss Alps and called humus-silicate soil. A prerequisite for ranker distribution is a limited nature of chemical weathering by climatic conditions. These conditions exist in the nival and Alpine regions.

The name "ranker" was suggested by Kubiena and denotes "deposits on steep slopes." These soils are being continually denuded and do not have a thick profile. In the first stage of development (the protoranker) the soil has a thin humus horizon consisting of slightly decomposed plant and animal residue, quartz particles and silicates. The reaction is very acidic. Under especially unfavorable conditions a "tangel ranker" is developed, which then forms so-called primary podzols in contrast to secondary podzols, which are the result of the completion of a full cycle of ranker-brown forest-podzol.

The next stages of ranker development—the mulliforme and mull—differ only in the character of the humus. Mulliforme humus consists of a mixture of semi-decomposed plant and animal residue; animal residue has decomposed considerably better. The organic part is not associated chemically with the mineral part. Humus in the mull stage is the totally humified residue of living organisms closely associated with clay. Earthworms play a large role in the formation of humus clay complexes. Mullranker is found on basic rocks. Tangel humus is developed under woodwaxen and juniper thickets which provide a very large amount of litter. Tangel humus differs from coarse humus in that it does not form the ashes of humic acids.

Red and brown tropical clay loams (limos rojos u pardos). Described are the physico-geographic conditions and the soil formation factors in the tropics and subtropics. All soils of these regions are divided into two great groups. In the first group are included clay soils having a gel content up to 75%; they are very plastic when moist, and hard when dry. Water cycle conditions are extremely unfavorable. These soils often have two different layers: an upper, dry, and hard layer, and a lower, moist, and plastic layer.

Friable allite soils are combined in the second group; they also contain a large quantity of gels, primarily sesquioxides, and conduct water well.

Red and brown clay loams are developed under the same conditions as terra rossa and terra fusca but are developed on acidic rocks. Generally speaking, these clay loams are typical of tropic and subtropic regions, but owing to their great stability, occur as fossil soils in Central Europe.

Brown clay loams have 3 genetic horizons, like the brown forest soils, but differ from the brown forest soils in the forms of iron content. As in terra fusca the iron in brown tropical clay loams has been peptized by colloidal silicic acid and produces, together with incrustated structures, films about the soil particles. These forms of iron determine certain soil properties: a very compact structure, plasticity, impermeability to water. Water flows along the surface, without entering the soil.

Chemical weathering is intensive. Soil reaction is slightly acidic, sometimes the carbonates are accumulated in the upper horizons.

Brown clay loams are well preserved in a moist climate; in dry regions they are stony (terrosa), then they change from lustrous to dull; iron forms into coagulated masses and the soil resembles a brown forest soil of the Mediterranean subgroup.

Another subgroup of brown clay loams are the podzolized soils formed during leaching of a part of the peptized iron from the profile. They were found in Paris and, as relict or buried soils in the mountains of Algeiras.

Red clay loams are also rich in colloidal silica; the iron is in the same state and produces red incrustations and concretions. Like the relict soils, the red clay loams are found in Southern Europe, sometimes with brown forest soils (with the Central European and brown subgroup) and are often covered by them. All properties of red and brown clay loams are very similar; they differ only in that the red clay loams are found in a dryer climate, the iron is more severely degraded and the soil has a redder color.

Together with the red clay loams we find in the tropical countries red earths (*tierras rojas*). Their properties differ sharply from the proper-

ties of red clay loams. Red earths have a stable porous structure, do not swell during the moist state and are non-plastic. The ratio of SiO_2 to R_2O_3 is considerably lower than with clay loams and the iron forms immobile stable red coagulated masses. In the transitional forms to laterites there is formed on the surface of the soil a crust of hydrargillite which is easily determined by double refraction.

Laterites. In the chapter on laterites we find a great wealth of information already well-known to the Soviet reader on this subject. Therefore, we shall dwell very briefly on only the problem of laterite origin.

Several authors consider that laterites are formed when the level of ground waters is unstable and drainage difficult. When the level of ground water drops, ferric hydroxide becomes ferric oxide; aluminum in the form of dissolved aluminates becomes immobile in the form of amorphous hydrargillite, when crystallized hydrargillite dries. This concept of laterite development presumes that they are similar to gley in a hot climate. In addition, the lateritization process is compared with the podzolic process; the B horizon of podzols corresponds to the laterite horizon. During destruction of the soil the laterite horizon comes to the surface and another soil may be developed on it. This horizon having a red or gray-yellow clay horizon located below is evidence of the lateritization process.

To explain the movement of sesquioxides the following ideas have been advanced: alkalinity of ground waters, protective influence of the salts of humic acids or of silica, as in red tropic clay loam and terra rossa. This last concept has enabled Kubiiena to presume the existence of an initial stage of red clay loam having a porous or spongy laterite structure and a surface crust of hydrargillite.

In B. Dietrich's opinion, sesquioxides move as the result of a change in the pH value during dry seasons associated with a capillary rise of solutions.

The parent material is of no great significance in laterite development; however, laterites are developed with more difficulty on acidic rocks.

CHRONICLE

SEVENTH INTERNATIONAL CONGRESS OF SOIL SCIENTISTS

I. N. ANTIPOV-KARATAYEV

As we know, the Seventh International Congress of Soil Science met August 15-24, 1960 in Madison, Wisconsin, USA.

The sessions of the Congress and of its commissions took place within the confines of the University of Wisconsin.

The Congress was organized chiefly by the American Society of Soil Science. Richard Bradfield, Professor at Cornell University (N. Y.) and well-known soil scientist and chemist, was chosen President of the Congress at the Sixth Congress. Charles Kellogg, also a well-known American soil scientist was chosen Vice President.

Specialists of many nations of the world participated in the activities of the Congress. Twenty-six delegates from the Soviet Union attended: I. V. Tyurin, G. S. Davtyan, S. N. Ryzhov, P. A. Vlasyuk, U. U. Uspanov, F. V. Turchin, I. N. Antipov-Karatayev, G. A. Aliyev, I. S. Rabochev, D. M. Guseynov, Ye. V. Lobova, N. N. Rozov, Ye. N. Rudneva, Ye. V. Rubilin, N. A. Kachinskiy, A. V. Peterburgskiy, P. G. Aderikhin, V. A. Frantseson, N. P. Karpinskiy, V. F. Shubin, E. A. Shtina, L. N. Aleksandrova, Ye. S. Blazhniy, N. L. Blagovidov, G. M. Tyurina, and N. V. Karpenko.

Included among the delegates of Soviet scientists was member correspondent of the Academy of Sciences, USSR, Professor V. A. Kovda, acting as Director of the Science Department of UNESCO (Paris). The Soviet delegation read 22 scientific reports at the Congress; one of these reports (by I. V. Tyurin) was presented at the Plenary Session; the other reports were presented at sessions of the separate commissions or at joint sessions of two or more commissions. The Fifth Commission (devoted to genesis, geography, and cartography of soils) had the greatest representation of Soviet delegates, followed by the Fourth Commission (on soil fertility). The Third Commission (on soil biology) had the weakest representation, with no representation at all on the subject of soil mineralogy.

As we know, in preparation for the Seventh International Congress, the All-Union Society of Soil Scientists formed the Organizational Committee, the activities of which made it possible to submit simultaneously a large number

of Soviet reports to the Preliminary Committee of the Congress (in the USA); to prepare and publish four collections of reports (All-Union, Ukrainian, Latvian, and Tadzhik) which were presented at the Congress and which aroused great interest among delegates of various nations. Our soil maps of the USSR and of the world presented at the exhibit of the Congress were also viewed with great interest.

Three hundred and twenty-nine reports were heard and discussed at the Congress.

In this article we shall consider only briefly the reports heard at the Plenary Sessions of the Congress. The basic slogan of the Congress was participation of soil scientists of the world in battling hunger ("Promote Peace and Health throughout the World by Alleviating Hunger through Soil Science").

The first session of August 15, was devoted to the opening of the Congress, where welcoming addresses were made by the Governor of Wisconsin; Robert Lewis, Adviser on Agriculture; Conrad A. Elvehjem, President (Rector) of the University of Wisconsin; Dr. Datt of the Indian Society of Soil Scientists; V. A. Kovda, Director General of UNESCO; and by representatives of European delegations.

The longest speech was made by the Director General of FAO of the United Nations, Dr. Sen, who pointed out that approximately 50% of the population of the world is suffering from a shortage of food (in South America, Africa, and Asia). It is contemplated that in one century the population of the world will double and if we do not change the nutrition status of the poor starving peoples, irremediable poverty and disaster will result. About 200 years ago a similar situation arose in Europe, but since that time Europe has achieved enormous progress in the field of agriculture and has conquered starvation and poverty. According to Dr. Sen's report, there is presently being worked out a general program for rendering real aid to backward countries. The FAO will create special scientific centers for immediate and prospective studies including problems of reclaiming and irrigating new lands, utilizing fertilizers, and developing technical procedures and machinery. In this regard we are not forgetting the introduction into agricultural practice of achievements in the field of agronomy in such countries as the USA,

Japan, etc. We must render concrete assistance, for example, to Egypt, Iraq, and South American countries, where there is much free land requiring irrigation and fertilization. A 10-year plan has been worked out by the FAO for India where the problem of increasing field productivity is extremely acute. The FAO has organized a large number of experiments on the use of fertilizers for which a sum of \$2 million has been appropriated for one year. Dr. Sen has appealed to the soil scientists of the whole world to join in the fight against the starvation of half of the earth's population.

The address by Dr. Charles Kellogg was devoted to the problem of the change in the productivity of United States land during the period 1927-1959 (that is, approximately, over a 20-year span), (Productivity of the Arable Soils of the United States 1927-1959). Unfortunately this report was not published. The report contained a wealth of illustrations. The basic points of this report were:

1. After 20 years of applying the scientific principles of agricultural practice, the productivity of agricultural crops (soybeans, wheat, etc.), has almost doubled, owing to the use of differentiated methods of land utilization and fertilizers (chiefly nitrogenous, phosphorous, and potassium fertilizers); fertilizer application has increased approximately five-fold during this period of time.

2. Owing to the broad mechanization of agricultural production during this period there has been approximately a 65 percent reduction in manual labor.

3. Further use of fertilizers is intended to stabilize the high harvests already attained; application of nitrogen fertilizers even on chernozem soils (Truog) is effective.

4. The Soil Conservation Service has played and continues to play a large role in this process. This service has engaged in a detailed study of soils and development of practical measures. In this sense, a so-called "three-sided approach" is being employed: study of relief, soil, and fertilizer. The soils are divided into detail classification units; this concerns particularly plowed land. The soil science strives to standard practices to be used by farmers economically. Assumed as the basis for the measures to be recommended are the following soil properties: the water regime, the oxygen regime, the nutrient regime, and contamination of soils by pests.

5. Introduction of scientific achievements into production has recently been substantially increased by mutual contact between farmers and scientific institutes in the field of agriculture.

Kellogg at the conclusion of his report dealt with the shortcomings of scientific investigations; failure to coordinate activities among experimental stations; cumbersome nature of the system of investigations, etc. As a result, in the speaker's opinion, we cannot take everything from American research in organizing corresponding activities in European and other countries of the world.

The final report at the opening of the Congress was a brief address by the President of the Congress, Professor R. Bradfield, on the subject "Opportunities for Soil Scientists in Freeing the World from Hunger." He advanced the idea that soil scientists should play one of the leading roles in this struggle. The problem of increasing crop productivity and reclaiming new lands is of primary importance because the shortage of food will limit the increase in world-population. He stated that we must utilize the fallow lands in the tropics¹ and vast deserts. Examples of high corn yields from the Mississippi Valley, plus rice in the USSR and Great Britain were cited. These high yields must be cultivated systematically. In the days to follow reports were heard at the Plenary Sessions of the Congress on the most important problems of present-day soil science, for example:

R. Brewer (Australia): The Petrographic Approach to the Study of Soils.

I. V. Tyurin (USSR): The Contribution of Pedology to the Development of Agriculture in the USSR.

D. K. McKevan and P. W. Murphy: The Influence of Soil Animals on Soil Formation.

Joshioki Izhizuka (Japan): Application of Physiological Studies to the Problem of Fertilizing the Rice Fields of Japan.

H. Deuel (Switzerland): Interaction between Inorganic and Organic Soil Constituents.

H. Frese (FRG): Do we have a scientific concept of Soil Cultivation? (Haben wir ein Konzept fuer eine Wissenschaft von der Bodenbearbeitung?)

L. A. Richards (USA): Advances in Soil Physics.

It can be said of Brewer's report that it contained a wealth of illustrations, microslides, and photographs of soil structural units. Increased attention was directed at the Seventh Congress of Soil Scientists to the parent material of soils and its effect on their properties and classification. The method described by the speaker and the generalization of the results approach the quite well-known method of Kubiena and his doctrine on the structure of soil units.

Following are the basic conclusions of the author:

1. Soil mass is extremely heterogeneous.

2. Soil profile descriptions are not fully valuable without petrographic investigations.

3. Analyses of a soil mass, on the whole, cannot yield what can be obtained by studying the

¹ A special symposium at the Congress on August 18, covering 8 reports was devoted to the problem of reclaiming and cultivating the soils of tropics and sub-tropics.

individual components, their distribution, and combinations in soil.

4. Physical properties of a soil mass depend upon its structure and fabric, especially upon the character of "plasma."

5. Genetic study of the weathering and soil-formation processes can be made by using the petrographic method provided the initial parent material is examined.

6. Structure and fabric of soil are of great importance in the interrelationship between soil and plant.

7. Experimental studies of the soil formation process may be controlled by using the petrographic method.

The report by I. V. Tyurin (published in this issue of *Soil Science*) has greatly aroused the interest of the delegates inasmuch as the problem of the relationship between soil science and agronomy is one of the most important subjects at the Congress.

The report of McKevan and Murphy examines the complex method of studying soil fauna: a combination of the process of extracting animals from the soil mass and using fine microslides. The authors divide the representatives of soil fauna into three groups: microfauna (including nematoda), mesofauna with animal size about $100\ \mu - 1\ \text{cm}$. (small Annelida, Arachnida, Myriapoda) and the macrofauna (mollusks, worms, Arthropoda, Vertebrata). The report examines the problem of the multistage development and establishment of the biocomplex of soil during its formation. For these purposes soil fauna has been studied at various stages of rendzina development (from Prorendzina to fully developed soil). In conclusion the soil forming activity of soil fauna was discussed.

The report by Ishizuka was devoted to the problem of synchronizing the use of mineral fertilizers with agricultural crop growth and development phases associated with maximum consumption by crops of nutrients so as to achieve maximum production output.

The principal food crop of Japan—rice—was used for this study. At the present time in Japan areas covered by rice have been reduced approximately 20 percent, in order to expand production of oats, red clover, and grain, intended for fattening beef cattle (a source of protein for the country's population in connection with the curtailed use of the ocean's resources). Use of fertilizers for rice should increase rice productivity, on an average, by at least 20 percent. It has been shown that by introducing crop rotation comprising rice (5 years in succession), oats with undercover of red clover, red clover, and grain, the rice productivity is increased. Rational use of fertilizers may further increase yields to the level required. Japanese scientists have studied such problems as:

a) absorption of nutrients by rice and their use at various stages of crop growth; b) effect on this process of the location of rice growth (north, south of the country); c) role of each

leaf on the stock in developing the crop as a whole; d) how to use the same amount of fertilizer so as to obtain maximum harvests. Basic principles in the use of nitrogen fertilizers as a foliar application; and e) transformation cycles of fertilizers in soil and their entry into plants.

As the result of extensive studies the conditions under which nutrients are utilized to the maximum extent by crops (Table 1, page 106) have been determined.

Dr. Mutsui considers it expedient to apply nitrogen fertilizers on foliage when asparagine is not found in the young rice leaves.

Deuel, in his report, examines soil as a chemical, or more precisely, a biochemical laboratory where organo-mineral compounds are synthesized within and without the organisms. These compounds in the various soils and in the various horizons of the same soil are not identical. The following inorganic elements and their compounds may be components of the organo-mineral compounds: monovalent ions, multivalent (polyvalent) or oligovalent ions (oligomery), clay minerals, sesquioxides. Acids and amines of low-molecular composition, multi-base acids and amino acids, fulvic acids, polypeptides, polysaccharides and humic acids are the organic components in the organo-mineral compounds. Depending upon the size of the components, the morphology of the organo-mineral compounds of soil may vary: from fine laminae to compact aggregates. The relation between the components in the organomineral compounds may be realized by Van der Waals' forces, ionic bonds, coordinated, and also covalent forces. To identify the separate organo-mineral compounds Deuel suggests using the following indirect methods: fractional peptization of soil; fractional extraction of the specific compounds; their special dissociation (degradation); determination of functional groups; characteristics of individual inorganic and organic components, their tendency toward complex formation, dispersion, coagulation, etc. The report also discusses the problem of the importance of organo-mineral compounds in soils during transportation of the chemical elements through the soil profile (the podzol formation) during structure formation, in plant nutrition, etc. Unfortunately, however, very little experimental data were presented.

Freze, in his report, brought up the need of fully developing the science of soil cultivation. In the author's opinion, the following problems should be resolved by soil science:

a) The qualitative, and, as much as possible, quantitative determination of the properties of soil (of the genetic, morphological, physical, chemical, and biological properties) which change under the influence of soil cultivation.

b) Why and how do meteorological conditions and soil cultivation and its alternating influence affect these properties.

c) What requirements do agricultural crops in a given area place on these soil properties?

d) How can we change the individual properties or their complex for these purposes?

Table 1

Conditions for the maximum utilization of nutrients by crops

Periods of use which guarantee normal crop growth	Time of maximum utilization
<u>Nitrogen.</u> From start of growth to time of blossoming.	10 days before formation of first blossoms to time of full blossoming.
<u>Phosphorous.</u> From start of growth to end of cultivation.	From start of tillering to start of formation of first blossoms.
<u>Calcium.</u> From start of growth to end of maturing.	From start to end of tillering.
<u>Magnesium.</u> From midway point of tillering to time of blossoming.	From time of first blossoms to full blossoming.
<u>Sulphur.</u> From start of growth to end of management.	From start to end of tillering.

The author places particularly great demands on soil physics, because soil cultivation, first of all, changes the physical properties of soil which, in turn affects the soil's chemical and biological properties. In the field of soil physics various methods (research and control), concepts, and scales are being used but are not coordinated.

With regard to what has been said the speaker proposes placing the problem of soil cultivation for study on an international scale.

In Richard's report entitled "Advances in Soil Physics" only one phase of physics was discussed, namely the properties of soil moisture.

In his report Richards substantiated the province of soil moisture available to plants based on a theoretical and experimental point of view (by the tendency of soil to deliver water when a suction force equal to 15 atmospheres and $1/3 - 1/5$ atmosphere is applied). The methods proposed by Richards are being widely used in many western countries, especially in the USA.

We may conclude from this brief discussion that the important problems of soil science were treated at the Plenary Sessions of the Seventh Congress in the hope of studying them again on an international scale. A detailed report of the scientific problems of soil science was made at sessions of the separate committees. It would be appropriate here to present a few of the problems which came up for discussion at commission sessions.

In the program of the first commission (on soil physics) 44 reports were made on the following problems: 1) physics of soil moisture; 2) energy balance of the soil surface; 3) soil structure; and 4) methods of studying physical properties of soil.

Included within the program of the joint sessions of the first and sixth commissions were 14 reports on the problems: irrigation and change of the physical properties of soils; soil moisture and agricultural crops. Two sessions

were devoted to the first commission jointly with the fourth and sixth commissions where problems on the availability of fertilizers to crops subject to soil moisture and the problem of crop growth subject to soil moisture level were discussed.

Within the program of the second commission (on soil chemistry) 3 sessions and 35 reports were devoted to problems on: 1) recent analytical methods of studying soils (X-ray-spectral method, polarographic method, potentiometric method, chromatographic method, etc.); 2) chemistry of soil organic matter; and 3) acidity and adsorption phenomena, organo-mineral compounds. At two joint sessions with the fourth commission 21 reports were discussed on problems: 1) radio-isotopes in investigations of the availability of nutrients to crops; and 2) second order elements (Second Elements: Mg, Fe, Si, S, etc.), and small elements (microelements).

At the 2 joint sessions of the second, fourth, and seventh commissions 17 reports were heard on the problem of phosphorus and its availability to crops. At 1 session jointly with the seventh commission 9 reports were delivered on the problem of the clay and oxide minerals of soil in their relationships to exchange-adsorption reactions and electrochemical phenomena. At a joint session with the fifth commission 11 reports were discussed on the problem of the physics and chemistry of soil formation (degree of soil saturation by calcium, and the oxidation-reduction state of soils, the electrokinetic potential in soils; dynamics of iron in soils; Ca-Al in soils; the physicochemical processes in soils of various groups, etc.).

At a joint session with the fifth and seventh commission 8 reports were made on the problem of rock and mineral weathering and soil formation.

At the third commission (on soil biology) 4 sessions (one jointly with the fifth commission) and 41 reports (including one report at the Plenary Session) were devoted to problems of: 1) nitrification and nitrogen fixation, 2) microbiological processes in the humification of organic matter, and ecology of microbes (nitrogen fixers, etc.); 3) interrelationships of plants

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and microbes and their activity; and 4) soil fauna and microorganisms and their role in soil formation.

The fourth commission (on soil fertility), besides the above sessions, heard and discussed at 6 sessions jointly with the second and sixth commissions 50 additional reports on the problems of: 1) soil diagnostics methods for determining the fertilizer requirement of crops (phosphorus and potassium); 2) soil fertility and plant nutrition; 3) development of the root systems of higher plants, and nitrification; 4) reaction of fertilizers added to soil; 5) liming, dolomitization of acid soils, role of organic matter in plant nutrition, and stimulation; and 6) fertilization of forest soils.

The work of the fifth commission (on the genesis, geography, classification, and cartography of soils) was very spirited. At 8 sessions of this commission and at 1 session jointly with the seventh commission 68 reports were presented; 23 reports were presented jointly with the second and third commission at 3 sessions. The problems under discussion were: 1) classification and geography of the soils of several continents (Latin America, Africa, Australia, Asia, Europe); 2) classification and geography of the soils of individual countries (South Africa, Angola, Portuguese New Guinea, Peru, Salvador, Israel, FRG, etc.); 3) the general principles of soil classification; 4) lithology, mineralogy of soils and their classification; 5) geomorphology and time as soil-formation factors; 6) genesis and classification of hydromorphous soils; 7) morphology and genesis of tropical soils; and 8) problems of soil regionalization.

Very lively discussions on many of the reports took place at the sessions of the fifth commission.

At the sixth commission (on soil melioration), besides the reports at joint sessions with the second and fourth commissions (see above) 2 sessions dealing with 19 reports were held on the problems of: 1) physics and chemistry of saline and solonetz-like soils; (ionic equilibrium, quality of water); 2) melioration of saline and solonetz-like soils; and 3) drainage and the physical properties of soils.

Not a single report was delivered at the Congress on problems of soil erosion and deflation. However, during trips throughout the United States, scientific experiments in and working examples of the melioration of eroded areas were observed.

Finally, at the seventh commission, besides the reports mentioned previously, heard at joint sessions with the second, fourth, and fifth commissions, and at the Plenary Session, 2 sessions dealing with 14 reports were held on the problems of: 1) effect of soil parent material and external conditions on the formation of clay minerals; and 2) the physicochemical properties of clay minerals and their complexes. Unfortunately, there were practically no systematic reports on soil mineralogy. During visits to several laboratories engaged in analyzing soil colloids and clay materials (particularly the laboratory at the University of Wisconsin headed by Profes-

sor Jackson), we did manage to acquaint ourselves to a certain extent with the system of methods used in studying soil and clay colloids.

Concluding this brief discussion of the activities of the Seventh International Congress of Soil Science, we ought to mention, as a weakness in the organization, that the lecture halls were not equipped with devices for a simultaneous translation of the reports from English to the other languages, officially recognized at the International Society of Soil Scientists; this deprived several delegates of the opportunity of participating fully in the discussions of reports.

A quite large special exhibition consisting of 3 sections was held during the Congress: 1) a scientific exhibit displaying most recent soil maps (on various scales) of various countries of the world, several methods of soil field studies, systems for laboratory analyses of soils; 2) an apparatus exhibit displaying the latest equipment, fertilizer samples showing their effectiveness (organized by several firms in the USA and Canada); and 3) a book display on specialized subjects dealt with at the Congress (organized by several publishing firms).

Of the organizational problems, we should point out that: 1) three Soviet scientists (Academician I. V. Tyurin, as President of the Fourth Commission; member correspondent of the Academy of Sciences, USSR, Ye. N. Mishustin, as Vice President of the Third Commission; and Ye. V. Lobova, Doctor of Agricultural Sciences, as Vice President of the Fifth Commission) were chosen members of the Presidium of the International Society of Soil Scientists for the next 4 years; 2) as a result of a proposal by the Rumanian Academy of Sciences, which was strongly supported by the Soviet delegation, the Congress decided to convene the next (Eighth) International Congress of Soil Scientists in Rumania. The well-known Rumanian soil scientist and member correspondent of the Rumanian Academy of Sciences, Chernesku, was chosen President of the International Society of Soil Scientists for the next 4 years; headed by Soviet scientists, I. V. Tyurin and V. A. Kovda, very fruitful discussions were held on the problems of the genesis, geography, cartography, and fertility of soils and, especially, on the problems of classifying soils, in particular, in connection with the presentation by American soil scientists at the Congress of a draft for a new general classification of soils. There were also beneficial discussions of reports by Soviet scientists on the soil map of Europe (I. V. Tyurin and Ye. N. Rudneva) and on the soil map of Asia (V. A. Kovda and Ye. V. Lobova).

The first scientific field trip (between New York and Madison) took place before the Congress convened, i.e., before August 15. Of the Soviet soil scientists only member correspondent of the Academy of Sciences, USSR, V. A. Kovda, participated in this trip. After the Congress, during the period from August 25 through September 7, a second and third scientific excursion was made, the second from Madison to Washington and the third from Madison to Berkeley, California. All the Soviet delegates took part in these trips. Moreover, one-day excursions were made to the suburbs of Madison (to experimental stations and fields of the University of Wisconsin, farms, etc.),

whenever there was a break in the activities of the Congress.

We should mention, too, the exceptionally fast bus ride through the country by the participants in these trips (for example, the third tour in which 16 Soviet delegates participated was made in 13-14 days, covering a distance of about 5,500 kilometers). Nevertheless, the Soviet delegates did succeed in observing: 1) profiles of zonal soils (here it would be appropriate to note that, unfortunately, we were not permitted

to gather soil samples and vegetation samples); 2) organization and nature of work on study and conservation of soils (the Soil Conservation Service) within the individual States as well as on study of irrigation and reclamation of soils (the Soil Reclamation Bureau); 3) the dry farming system; 4) the problems of forest soil science; 5) irrigation farming; 6) organization of agricultural science in universities and at the Agricultural Biological Center of the United States; and 7) the training of specialists in soil science and agricultural chemistry.

L. SMOLIK—MEMBER CORRESPONDENT OF THE CZECHOSLOVAKIAN ACADEMY OF SCIENCES

Professor Ladislav Smolik, a member correspondent of the Academy of Sciences and Director of the Soil Science Laboratory of the Czechoslovakian Academy of Sciences, died April 14, 1960, in Prague.

Smolik was born July 19, 1895 in Strevachi near the Yichina in Czechoslovakia. He studied under Professor Kopetskiy at the Institute for Agricultural Engineers in Prague. Upon completing his courses at the Institute in 1923, he received the title of Doctor of Technical Sciences. Smolik worked many years in the field of agriculture in Brno at scientific research institutes, later at universities and technical institutes, and in 1947 was appointed Professor at the Institute of Construction Engineering, having obtained this position following the death of Professor Ya. Kopetskiy. Here he followed the old Czech tradition of soil science established by Alfred Slavik.

Influenced by personal meetings with Academician K. K. Glinka, Smolik strengthened his soil chemical trend in research work and devoted himself to the problem of the chemical processes in soil formation. It is precisely in this branch of soil science that he did most of his work. Smolik became acquainted with many foreign soil scientists and took part in scientific

soil science conferences. During numerous trips abroad he became familiar not only with European soils but also with Asiatic, North American, and North African soils. The problem of increasing soil fertility in deserts was also of major concern to him. Professor Smolik carried on regular correspondence with foreign soil scientists. Russian soil scientists devoted to problems of soil genesis, and American soil scientists dealing with the problem of soil chemistry had a particularly great influence on him.

Smolik has written more than 200 scientific works, a large number of which are in several foreign languages. To be especially noted are an interesting study on humus which forms part of his earlier works (1924-1936) and many studies on soil colloids and their adsorption capacity. Generally speaking, these works are among the first in soil science in this direction. Several of his works are concerned with the study of soil reaction and the oxidation-reduction potential (1925-1946).

During his last years Smolik wrote text books entitled "Soil Science" (1957) and "Meteorology and Climatology for Engineers" (along with V. Struzhka, 1959). Professor Smolik trained a number of soil scientists and hydrobiologists in Czechoslovakia and, owing to his great capacity for work, he has become an example to his pupils.

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